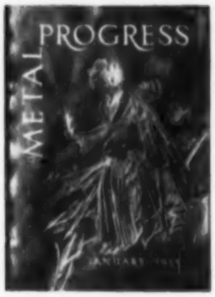
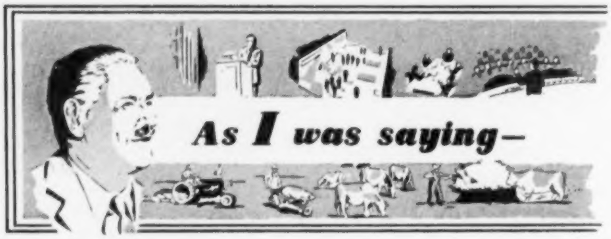
METAL PROGRESS

JANUARY 1953

IN THIS ISSUE



The cover aims to convey the idea that international cooperation, symbolized by national emblems around the skirt, is an instrument of peace.



WE SINCERELY hope you had a fine Christmas and that the New Year has started very auspiciously and will continue to bring you success and happiness, not only for the rest of the year but for all the years to come. I know you are all going to be kept busy and that is as you would want it. We all thrive on keeping our minds occupied and active, thinking only of our friends and not at all of those we do not like (if there are any such people – and knowing you as well as I do, I am sure there are very few).

Keeping our minds active and directed in forward-looking, constructive thinking surely will keep us busy.

It is just a short spell since the Congress and Exposition at Philadelphia was put to bed. Our mail has been flooded with letters from enthusiastic members and exhibitors all praising the event and agreeing that it was perhaps the best in the 34 years of these activities.

I guess those of us at headquarters are so close to the trees that we can't see the forest or evaluate it, so we are very happy to receive these accolades of commendation, even though we realize that the shoe is on the other foot. It should be we who tell you members and exhibitors that it was *your* efforts and contributions that hitched the wagon to a star and made that scintillating phenomenon streak across the industrial sky.

So here we are, talking about the past, when for quite some time now we have been looking into the future, planning and presenting two important events for '53.

The first will be the Western Metal Congress and the Western Metal Exposition at Los Angeles the week of March 23, with fine technical programs being presented by the A.S.M., A.W.S., A.S.T.M., A.F.S., and S.N.T. And, oh yes, the Royal Red Carpet will be shipped to Los Angeles to complement the largest industrial exposition ever held in the West.

The next event that has had our attention now for about a year will be the National Metal Congress and the National Metal Exposition, to be held in Cleveland, Oct. 17 through 23, 1953.

These events are challenges to all alike to make them better (they can't be bigger because they now occupy all available space in the nation's largest convention auditoriums) than their predecessors, however difficult to accomplish that challenge may seem.

What do you say? Shall we accept the challenge and go on to greater accomplishments?

Thanks, I knew you were with me, and with your help we will do it.

Cordially yours,

Bill

W. H. Eisenman, *Secretary*
AMERICAN SOCIETY FOR METALS

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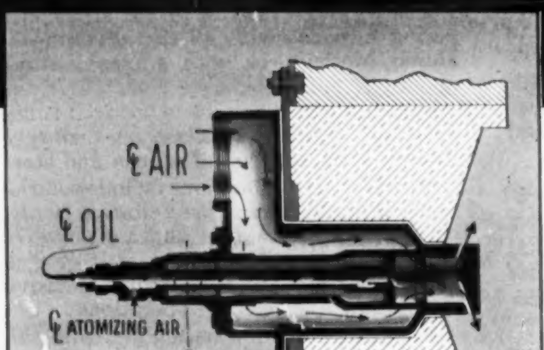
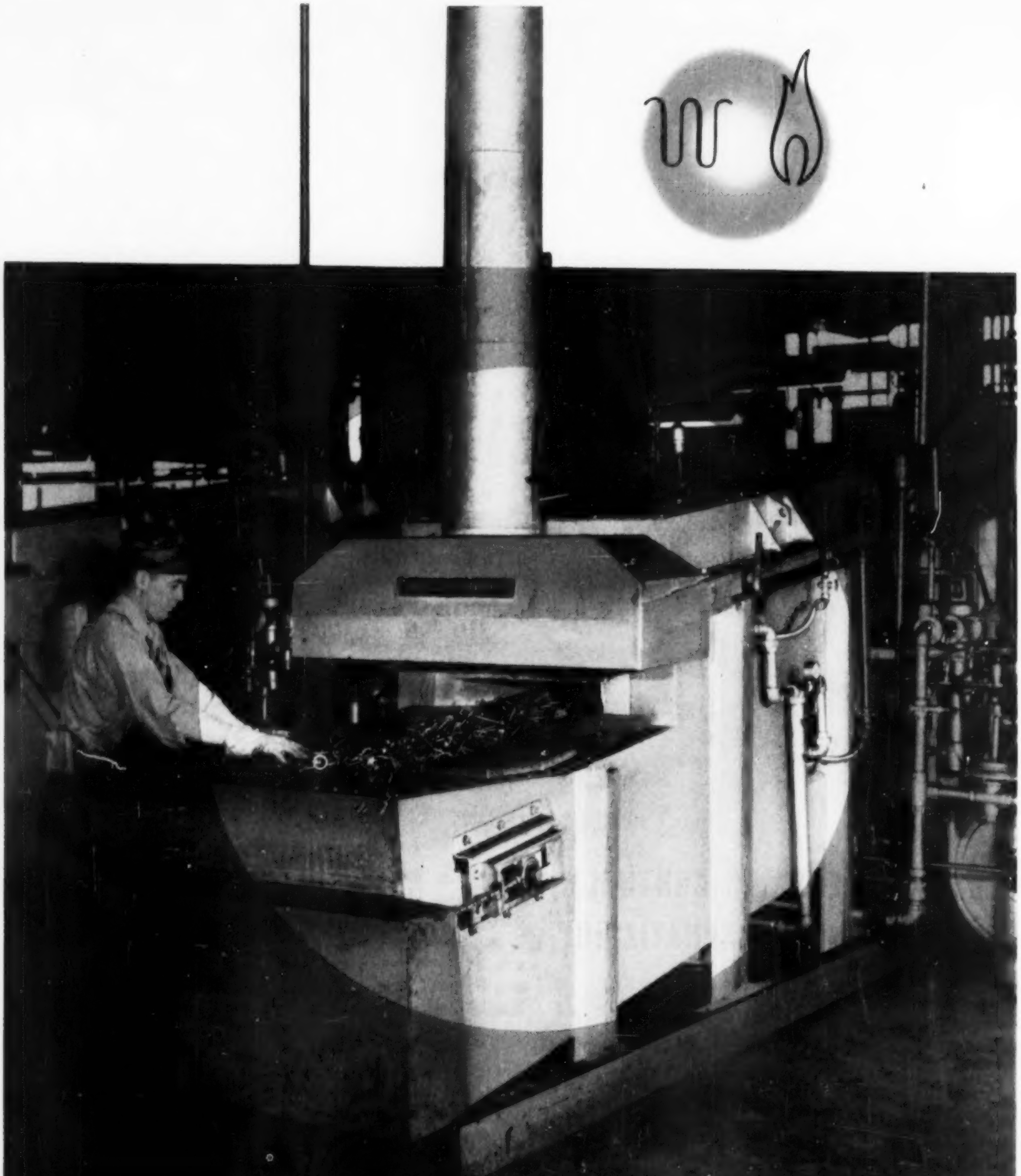
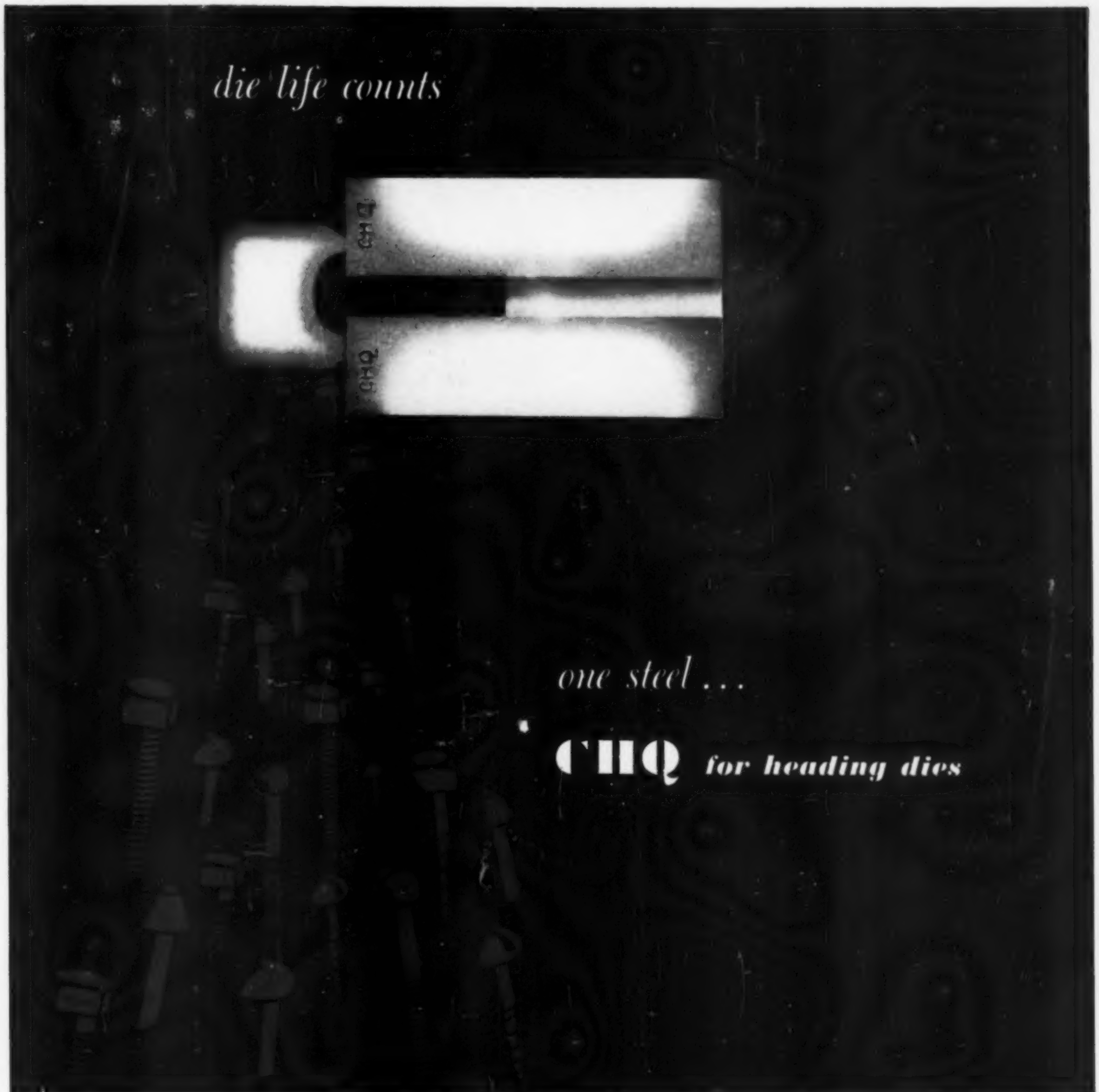
Precision burner improves forge shop practice... The BLOOM



DESIGNED AND DEVELOPED FOR DEFINITE APPLICATIONS

The Bloom HTR Burner is ideal for applications where a high rate of heat transfer is required. This burner is not susceptible to breakage and requires only normal maintenance in furnace temperatures up to 2800° F. It provides identical operation with either gas or light oil.




die life counts
CHQ
CHQ
one steel . . .
CHQ for heading dies

Here's the new
LINDBERG
CARBONITRIDING FURNACE
LINDBERG

News in 1940—production necessity today

ONLY a few years ago, the science of sensitive, accurate measurement was limited to laboratories. But today, this science is practiced every day in thousands of industrial plants by factory men . . . who don't have to be instrument experts.

Production men wanted to put this science to work, for they had long known that many processes would function at greater efficiency if temperature, pressure and other variables could be more accurately maintained. Although these potential benefits could be proved in the laboratory or in pilot plants, they could seldom be exploited fully in actual production.

Milestone in measurement

One of the main reasons was that existing industrial methods of measurement were not sufficiently accurate, sensitive or fast. Instruments with delicate mechanical balancing systems suffer inherent limitations . . . always require a compromise between sensitivity and ruggedness . . . and can provide only periodic measurements.

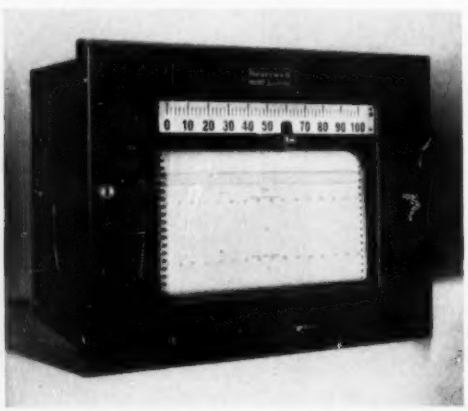
Then, in 1940, the advent of *ElectroniK* instruments swept away these limitations. By adopting an entirely new approach—electronic continuous balancing—these instruments revolutionized the concepts of industrial measurement. They placed laboratory accuracy and sensitivity at the disposal of the production man . . . with all the simplicity and ruggedness demanded by industrial service . . . *plus* speed of response never before economically practical.

Proved by years of performance

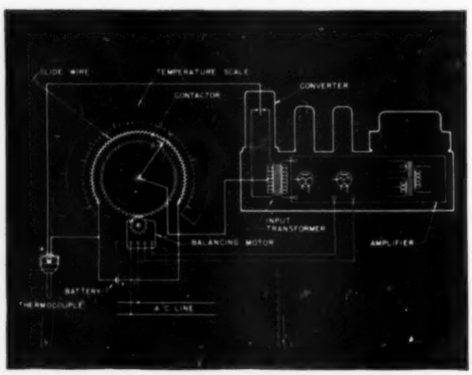
In the past thirteen years, thousands of plants have discovered almost endless applications where the superior performance of these instruments helps to improve operations. The more they learn about *ElectroniK* instruments, the more they call on them for increasingly complex tasks of measurement and automatic control.

Since 1940, the *ElectroniK* family has grown to encompass a host of new indicating, recording and controlling models . . . capable of measuring scores of different process variables . . . equipped with the most advanced types of automatic control. In anticipation of the needs of the future, Honeywell's intensive development program is bringing to readiness even more advanced equipment for tomorrow's process control problems.

Advanced need



A FAMILIAR SIGHT *to thousands of production men, scientists and engineers is this strip-chart **ElectroniK** Recorder, one of a complete family of indicating, recording and controlling instruments.*



POWER PLANT *of **ElectroniK** instruments amplifies a millionfold the minute electrical signals from thermocouples and other sensing elements.*

PRODUCTION HEAT-TREATING WITH LABORATORY PRECISION *helps evaluate new techniques at Ipsen Industries' new million-dollar laboratory. ElectroniK Controllers on panel at left provide precise regulation of critical temperatures.*

heat-treating methods

precise ElectroniK control

New heat-treating furnaces, and new ways of using them, go through their paces in the ultra-modern laboratory of Ipsen Industries, Rockford, Illinois. By means of tests under carefully controlled conditions, new equipment and techniques are scientifically evaluated before release for industrial use.

Precision is the watchword here . . . in heat-treating and in examination of results. In keeping with this objective, *ElectroniK* instruments were selected to control critical temperatures in heat-treating furnaces and atmosphere generators.

In the laboratory or on the production line, *ElectroniK* controllers are equally at home. They hold furnaces right at the specified temperature with the accuracy and constancy particularly vital to treating the new alloys. And their ability to stay on the job under tough factory conditions has earned them a reputation among production men.

You'll find *ElectroniK* controllers are the ideal partners for any kind of heat-treating furnace. Our local engineering representatives will be glad to discuss your applications in detail; call him today . . . he is as near as your phone.

Minneapolis-Honeywell Regulator Co., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Penna.

● **HONEYWELL SERVES THE WORLD** *through representatives in Argentina, Australia, Austria, Belgium, Brazil, Chile, Colombia, Cuba, England, Finland, France, Guatemala, Hawaii, Iceland, India, Indonesia, Italy, Japan, Mexico, New Zealand, Norway, Panama, Peru, Porto Rico, Scotland, South Africa, Sweden, Switzerland, Trinidad, Venezuela.*

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

UNICHROME
Trade Mark

News about

COATINGS for METALS

Metallic . . . . Organic . . . . Decorative . . . . Protective

Specifications on corrosion resistance met by these

Two Ways to Chromate-Finish Zinc

ZINC FINISH STAYS BRIGHT AS CHROMIUM

Zinc plate, when chemically treated in Unichrome Clear Dip and then fortified with a Unichrome Clear Enamel, provides a substitute finish which can satisfy exacting requirements. The Clear Dip forms a bright-as-chromium finish integral with the zinc, while the clear enamel adds extra wear and corrosion resistance to this protective finish without detracting from its brightness. This successful finishing system is in widespread use today on zinc die cast and steel products.

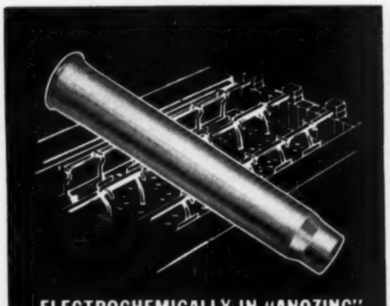
CLEAR ENAMEL SAVES THOUSANDS OF DOLLARS

A clear enamel over today's decorative chromium finish gives extra protection against moisture, handling, corrosives. Using a special Unichrome Coating, one well known manufacturer is getting not only superior protection on plated refrigerator shelves, but also greater film thickness at less cost than the coating formerly used. Savings reported for the year: $15,000.

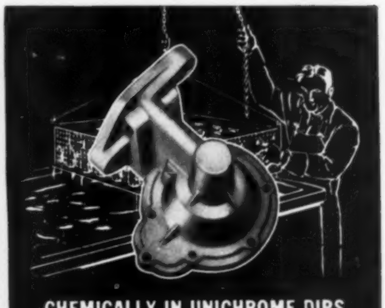
Better Protection Against Chemical Attack

Because Ucilon* Protective Coatings resist many strong chemicals, they're being used today in a wide variety of tough applications. On plating machines, for example. Also on bottling machines and on processing equipment. Use of these coatings means less corrosion and better appearance with less maintenance. Ucilon Coating Systems are available to withstand acids, alkalies, salt solutions, oxidants, moisture, petroleum products, alcohols, fumes and other corrosives. Write for Bulletin MC-4.

**Trade Mark*



ELECTROCHEMICALLY IN "ANOZINC"



CHEMICALLY IN UNICHROME DIPS

■ Government specifications which call for chromate treating of zinc plate, do so to assure protection against corrosion. Several methods of chromate finishing are available to do this job. This gives the user freedom to choose the particular process that's best suited to his product, and offers production or cost-cutting advantages.

Two Unichrome Processes are widely used today because they can not only meet or exceed specifications, but also provide substantial benefits to the user.

A TOUGHER COATING THROUGH ANODIZING

The Anozinc* process, using conventional plating equipment, produces black, yellow or clear chromate type coatings on zinc plated parts by means of current. An exclusive process, it provides a finish with not only the desired corrosion resistance, but also superior toughness while still wet. This means that parts can be handled at once, thereby minimizing the storage and drying space problem.

The Anozinc process can be set up in one continuous automatic cycle with the zinc plating, or for manual operations. Zinc plated steel shell cases are being turned out at a fast clip with this process, as are propeller blades and other vital work.

In forming conversion coatings, chromate treatments remove some of the zinc from the product. Consequently, there is a problem in recessed areas of the work, where zinc plates thinner than it does at the edges. Not with Anozinc, however. An anodizing process, it complements the zinc plating process. Its stripping action is less in recesses where the zinc plate is thin. With a straight chemical dip, more zinc would have to be deposited to compensate for non-selective stripping action.

UNICHROME DIP A SIMPLE PROCESS

Unichrome Dip Finishes, chemically produced, are adaptable for manual or automatic operation. They too inhibit corrosion and withstand exposure. Different solutions produce a black, olive drab, brass-yellow, iridescent yellow or clear chromate coating in 5 seconds to 2 minutes, depending on the solution used. These finishes, integral with the zinc surface, also make excellent bases on which to apply organic coatings.

As straight chemical processes, Unichrome Dips use simple equipment, need no generator or rectifier and minimize installation costs.

Unichrome Dips produce bright, glossy finishes. The black and olive drab finishes can provide the eye appeal of glossy enamel. Clear finishes are bright, and have an appearance similar to chromium.

BOTH ARE ECONOMICAL SOLUTIONS

Anozinc baths have exceptionally long life. Unlike chemical dips, they seldom need to be discarded. In mass production, this feature cuts operating expenses.

Compared with other dips, Unichrome Dips can save money, too. By using a Unichrome Dip instead of their "home made" chromate dip, one well known company cut cost of materials alone by one-third.

Write for Bulletin CC-1, or phone the nearest United Chromium office.

UNITED CHROMIUM, INCORPORATED

100 East 42nd Street, New York 17, N. Y. • Detroit 20, Mich. • Waterbury 20, Conn.
Chicago 4, Ill. • Los Angeles 13, Calif. • In Canada: United Chromium Limited, Toronto, Ont.

New facts for your file on U·S·S CARILLOY STEELS

In lift-type cultivators U·S·S Carilloy steels save weight, increase durability, and keep down costs

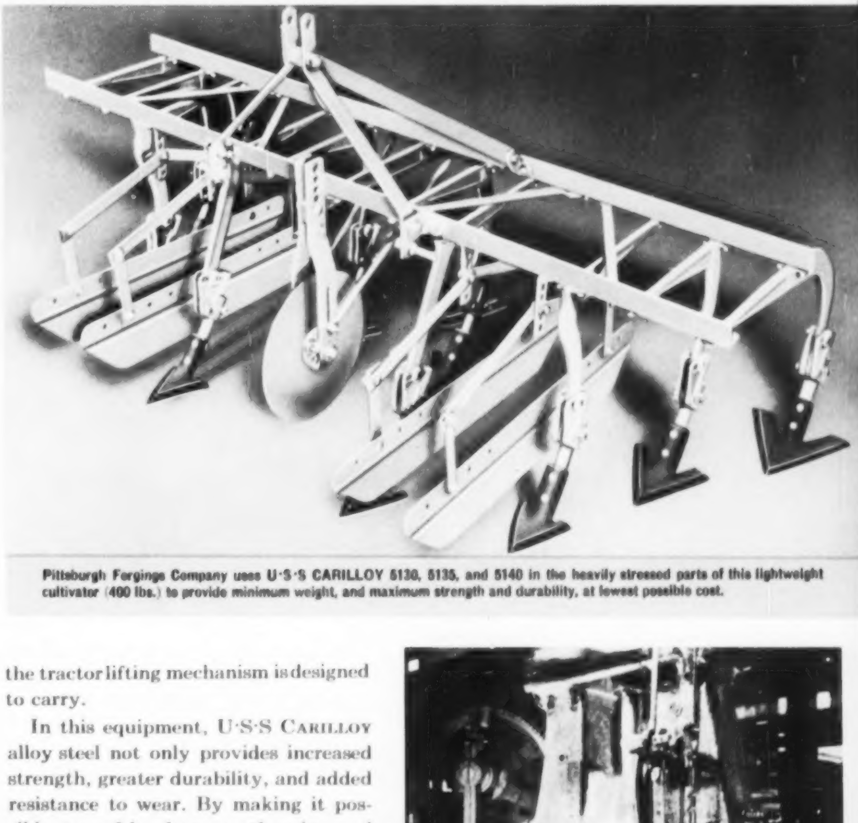
● To pack maximum strength into their heavy-duty lift-type cultivators, while keeping weight as low as possible, Pittsburgh Forgings Company uses U·S·S CARILLOY steels in the shanks, beams, and main frames of these rugged farm implements.

The excellent performance of this equipment is proof that many parts that must operate in extremely tough service can be made of alloy steels that do not contain critical elements. The three grades of U·S·S CARILLOY used in this application—CARILLOY 5130, 5135, and 5140—were selected years ago for the express purpose of providing minimum weight, maximum strength and durability, at the lowest possible cost.

CARILLOY steel construction provides the strength and toughness required to cultivate heavy soil at speeds up to 6 miles per hour, and has made it possible to reduce cultivator weight to only 400 lbs. This is about half that of comparable units made of ordinary carbon steel, and well below the limit which the tractor lifting mechanism is designed to carry.

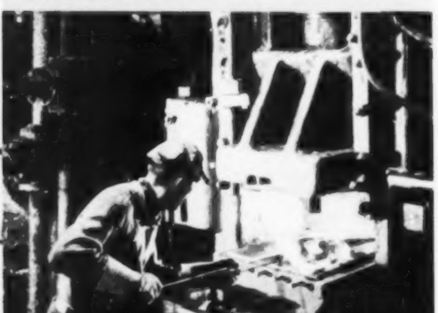
In this equipment, U·S·S CARILLOY alloy steel not only provides increased strength, greater durability, and added resistance to wear. By making it possible to safely decrease the size and weight of all heavily stressed parts, it reduces the amount of steel required, and enables the manufacturer to keep his costs well in line with competition.

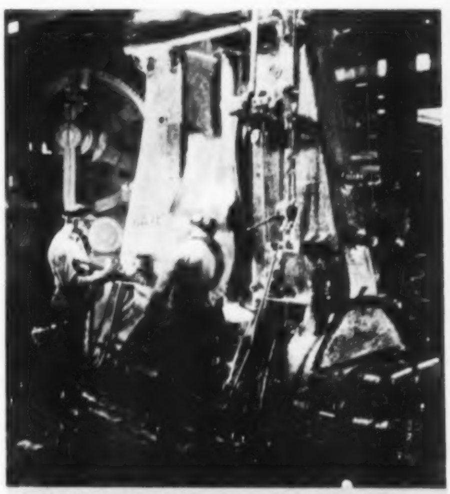
U·S·S Metallurgists who have had wide experience with similar applications of alloy steels, will be glad to assist you in selecting the steel best suited to your product. They can also recommend the best heat treating methods to use. If you need their help just call the nearest District Sales Office, or write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.



Pittsburgh Forgings Company uses U·S·S CARILLOY 5130, 5135, and 5140 in the heavily stressed parts of this lightweight cultivator (400 lbs.) to provide minimum weight, and maximum strength and durability, at lowest possible cost.

Excess metal left after forging is removed in this trim press. The piece is then straightened, bolt holes are drilled, and surfaces that must align exactly with other parts are accurately milled.





At Pittsburgh Forgings Company, precision parts for lift-type cultivators are forged from U·S·S CARILLOY bar stock. Here, beams are being forged to final size and shape in a steam hammer.

USS

UNITED STATES STEEL COMPANY, PITTSBURGH · COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. · UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

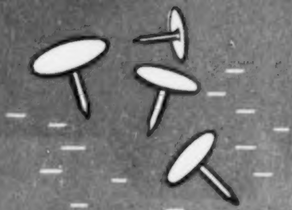
UNITED STATES STEEL

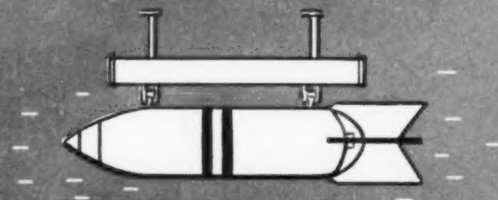
"My crew is as good as

UNITED STATES


Re-check YOUR
Cost Relief Zone!

FROM THUMB TACKS TO BOMB RACKS

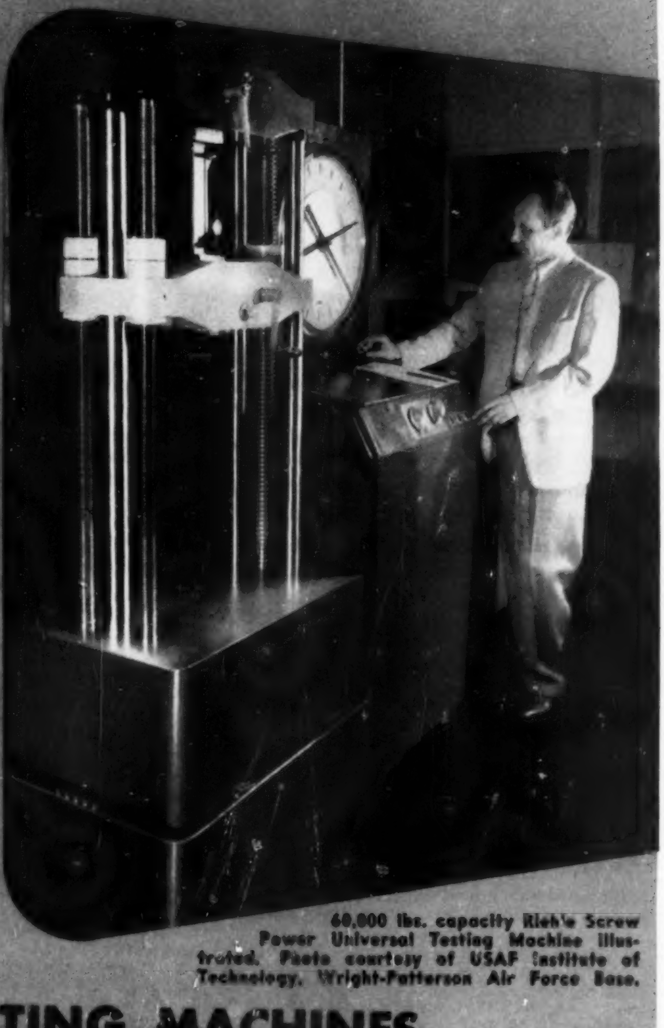




you can test practically anything with a

RIEHLE

UNIVERSAL TESTING MACHINE

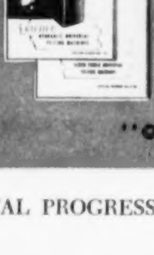


Every Riehle Pendomatic Universal Testing Machine is the equivalent of five testing machines in one because it has five standard scale ranges. You select the most logical range for your test; then, merely turn the selector knob and conduct your test. On the same Riehle machine, you can test specimens with relatively low-rupture-points or large, high-yield-point specimens. No accessories are needed. Guaranteed accuracy is within ½ of 1%.

Hydraulic and Screw Power Types

Riehle Universal Testing Machines are built with hydraulic loading unit or screw power loading unit. Each type is available in a variety of sizes, with capacities up through 400,000 lbs. Ask your Riehle representative or write our factory for illustrated catalogs.

60,000 lbs. capacity Riehle Screw Power Universal Testing Machine illustrated. Photo courtesy of USAF Institute of Technology, Wright-Patterson Air Force Base.



RIEHLE TESTING MACHINES

Division of AMERICAN MACHINE AND METALS, INC.

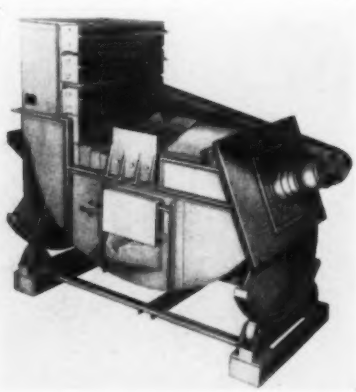
East Moline, Illinois

"ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS"

Engineering Digest

OF NEW PRODUCTS

MELTING FURNACE: Operating improvements for melting of ferrous and nonferrous metals are provided by the newly-developed noncrucible, direct-fired reverberatory furnace of the Eclipse Fuel Engineering Co. There is no time lost between pouring and recharging. Hot metal is always available for casting. Combustion normally wasted is used for melting or preheating cold metal in the hopper. Operations show that a melt of from 1200 to 1500 lb. of steel scrap is tapped within 30 min., depending on the size of scrap gates and risers (weighing from 10 to 150 lb.). Fuel consumption averages 55 to 60 gal. per hr. Fired by either oil or gas, standard models, with bath capacities ranging from 300 to 4400 lb., are now in production.



For further information circle No. 1 on literature request card on p. 32B

WEAR RESISTANCE: Flame-plating, developed by Linde Air Products Co., is a new method for applying hard, thin, precise coatings of powdered metals, such as tungsten carbide, on metal parts. It is being used to help solve frictional and abrasive wear problems. Extensive tests to date indicate that flame-plated tungsten carbide coatings have the desirable properties of sintered tungsten carbide, while at the same time avoiding some of the limitations of the sintered form. Tests have shown that the coatings have wear and abrasion resistance as good as, or better than, sintered carbides. Although several coating materials are being tested, all present commercial applications use tungsten carbide.

One of the biggest features of this new method is that the temperature of the base metal does not exceed 400° F. during the plating operation. This low-temperature deposition practically eliminates any possibility of a change in the properties of the part being plated and reduces to a minimum the chance that the part might warp. The bond between the base metal and the coating is mechanical — it is not a welded bond. Because of the way in which the coating is applied, there is no mixing of the coating with the base metal.

Flame-plating is adaptable to many different base metals in a wide variety of sizes and shapes. Steels, cast iron, aluminum, copper, brass, bronze, titanium, and magnesium have all been successfully coated. Flat areas, cylinders, spheres, internal areas, and many irregular shapes have been coated. Tungsten carbide coatings from 0.0005 to 0.020 in. thick are being applied.

For further information circle No. 2 on literature request card on p. 32B

AIR WEIGHT CONTROL: A new compensator for foundry cupolas, announced by Foxboro Co., eliminates the effects of blower pulsations on control. Uniform combustion through control of air weight is practical, even where positive displacement blowers are installed on blast lines. The compensator adjusts the action of the controller, automatically correcting the rate of air flow for variations in atmospheric temperature and pressure. A snubbing device damps out the throbbing effect resulting from the use of certain types of blowers and permits the controller to respond

WELDING AND FORMING: The demand for a combination forming and welding machine has been answered through the joint efforts of Struthers Wells Corp. and the Federal Machine and Welder Co. Machines are presently being produced to form and weld a wide range of appliance cabinets and liners. The combination machine consists of a Struthers Wells tangent bender with a Federal Machine and Welder welding component mounted on a beam which is raised and lowered with each machine sequence to make the forming operation possible. The material is first placed in the lower dies of the bending machine and then the operator presses a button to start the fully automatic forming and welding cycle. The bender forms the cabinet to the desired shape and the last bender operation actuates a limit switch which initiates the automatic welder cycle. At this point, the welder beam is lowered and automatically latched to the male bender die. The welding guns then engage the cabinet and make the welds. The guns retract, the beam unlatches and raises to dwell position. At the time the welding beam starts to retract, the bending wings of the tangent bender also return to their initial position. The cabinet assembly is then lifted so it will easily clear the male die for unloading.

For further information circle No. 3 on literature request card on p. 32B

only to true changes. More than 1400 instruments have been installed in foundries throughout the world.

For further information circle No. 4 on literature request card on p. 32B

DYE PENETRANT INSPECTION: A more reliable dye penetrant test to locate cracks in any solid material has been announced by Magnaflux Corp. A packaged kit is available, easily carried, for inspection of small questionable areas and remotely located parts at any time. Features include spray can sealing of messy constituents, for cleanest and most conveniently rapid spray application to any part. For plant maintenance of mechanical equipment or for tool inspection in any industry, for weld, casting, or forging inspection, or for overhaul tests of any transportation equipment, the Spotcheck kit is carried in one hand to the parts in question, and tests for cracks carried out in but a few minutes. No power or special lights are required. The dye penetrant is pressure-can sprayed on the clean surface to be tested. Then a cleaner is sprayed on the surface, and removed by a quick wipe. An even coat of white developer is brushed on, and inspection follows in a few seconds. Cracks show up as bright red

lines, and pores or leaks in tanks show as bright red spots.

For further information circle No. 5 on literature request card on p. 32B

SEAMLESS LIGHT-WALL TUBING: Superior Tube Co. has announced an increase in the size range of its seamless light-wall tubing from 1¼ to 2⅛ in. o.d. max. Heretofore, specialty tube mills have offered the larger diameter light-wall stainless tubing only in welded grades. The increased

ALUMINUM ALLOY: Development by General Electric of a new alloy called "Cond-Al" has enabled the company to begin manufacture of steam turbine-generators which are 35% more powerful than any of their type now in existence. Cond-Al is composed of aluminum, with very small quantities of iron, magnesium and silicon. The alloy's light weight, high conductivity, and resistance to various stresses in high-speed, high-temperature operation make larger turbine generators possible.

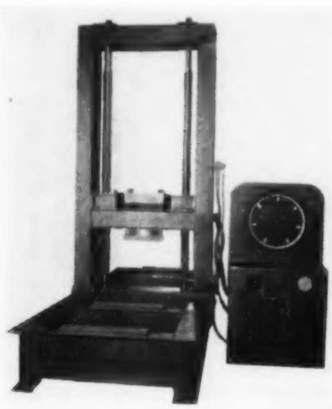
For further information circle No. 6 on literature request card on p. 32B

size range is expected to increase the number of applications where pressures are too great for welded tubing.
For further information circle No. 7 on literature request card on p. 32B

AUTOMATIC ATMOSPHERE CONTROL: The Lindberg Engineering Co. has released data on a device to control automatically and to record the carbon potential of furnace atmospheres. The Lindberg Carbotrol is a

proportioning instrument which enables the heat treater to set the furnace atmosphere in equilibrium with any steel. The new instrument is now being subjected to field tests.
For further information circle No. 8 on literature request card on p. 32B

TESTING MACHINE: A new floor-type, universal testing machine permitting great working capacity on a finished machine pad bed of 4 x 15 ft.

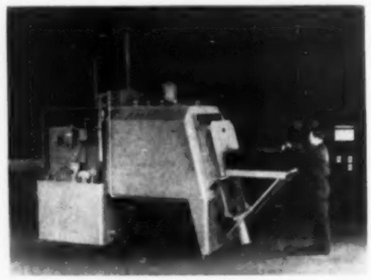


has just been announced by the Young Testing Machine Co. Designed especially for large specimens of work such as bridging members and aircraft wings, this 200,000-lb. machine offers a number of new and unique features. The crosshead is driven by a Thymotrol motor mounted directly on the crosshead instead of at the bottom of the machine. Raising and lowering of the crosshead on fixed screws thus permits a more direct and rigid drive with less torsion in the screws. Speed range of the motor is 20:1, providing an over-all loading speed of 0.025 to 0.5 in. per min. and a traverse speed of 15 in. per min.
For further information circle No. 9 on literature request card on p. 32B

COLORED SILICONE FINISH: Sicon, a silicon-base finish with heat resistance properties, is now available in decorative colors, according to the manufacturer, Midland Industrial Finishes Co. It stands up under temperatures in the 400 to 500° F. range. Tans, whites, beiges, blacks and golds have already passed laboratory tests and have been used in production.
For further information circle No. 10 on literature request card on p. 32B

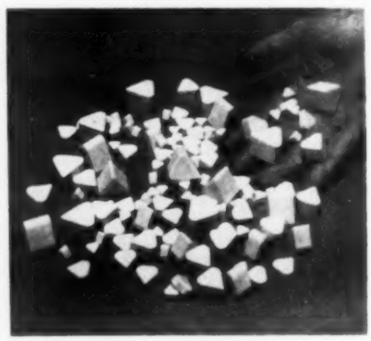
FURNACE: A new 400 lb. per hr. automatic heat treating unit featuring 100% forced convection heating has been announced by Ipsen Industries, Inc. The new unit operates at temperatures up to 1850° F., and has complete automatic straight-through operation from heat through cooling or oil quench. The unit is sealed to provide absolute atmosphere control

during the entire heating and quench cycle, assuring bright scale-free work on all types of heat treating processes such as carburizing and carbonitriding. The forced convection system employs the use of non-alloy radiant heating tubes, baffles, and a powerful fan mounted in the roof of the furnace. The tubes are spring loaded



and positively sealed by means of compression bellows and are designed for either gas-fired or electric heating elements. The heating tubes are mounted vertically between the brick insulation and an interior demountable baffle. A powerful alloy fan forces the endothermic atmosphere around the baffles, past the radiant tubes, and then up through the floor and the work. The fan is short-coupled to a special slow-starting motor with water-jacketed bearings and built-in safety switch.
For further information circle No. 11 on literature request card on p. 32B

TUMBLING ABRASIVE: Pebs, a newly developed tumbling media for barrel tumbling, deburring and finishing, has been introduced by Crown Rheostat & Supply Co. Made of



white ceramic, Pebs are of triangular shape, available in a variety of sizes. By selecting the proper size, lodging of pieces in holes is eliminated.
For further information circle No. 12 on literature request card on p. 32B

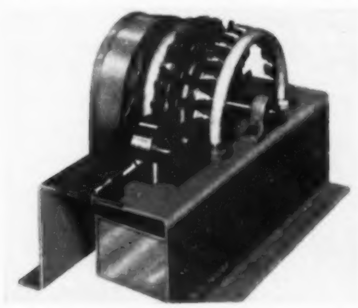
STEREO-MICROSCOPE: Used for any inspection operation, examination, counting or checking, the Edmund Scientific Corp. stereo-microscope provides an exceptionally wide field.

Fixed three-power objective, with three pairs of matched eyepieces, give powers of 15, 30 and 45 ×. The instrument is removable from its base for mounting on equipment, bench, or separate stand.
For further information circle No. 13 on literature request card on p. 32B

ULTRAVIOLET INSPECTION: The new Burton magnifier black light complies with Air Force Spec. MIL-I-6866 covering lights used for fluorescent penetrant inspection. Twin

tubes produce 3660 Å ultraviolet energy which is directed up on the inspected surface. There is no back glare or heat to affect the operator's perceptions. The unit is 7 by 5 by 2 in., weighs 30 oz.
For further information circle No. 14 on literature request card on p. 32B

HEAT CHECK TEST: Thermo-Test, a new tool for determining the relative resistance of different metals to heat checking, has been developed by Henry G. Keshian. Test pieces are successively heated, stressed and cooled. This cycle is repeated until the specimen develops visible cracks



or heat checks. The number of cycles required to produce heat checks is indicated on a counter attached to the machine. As many as eighteen specimens can be tested at one time. Various metals used for molds, permanent molds, die-casting dies, drop forging dies, hot piercing mandrels, extrusion dies, hot rolls, and other tools or parts can be tested.
For further information circle No. 15 on literature request card on p. 32B

What's new

IN MANUFACTURERS' LITERATURE

16. Abrasive Unit
Bulletin 5212 on small dry-abrasive airblast unit for cutting hard materials and precision finishing. *S. S. White*

17. Air-Gas Mixer
Engineering and application data on air-gas proportional mixer in Bulletin L-300. *Eclipse Fuel Eng'g*

18. Alkaline Derusting
Bulletin on electrolytic process operated at room temperature, for derusting without acid. *Enthone*

19. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

20. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

21. Alloy Steel
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

22. Aluminum Bronze
Engineering manual on wrought forms of aluminum bronze. *Mueller Brass*

23. Aluminum Bronze
Data sheets for aluminum bronze coated electrodes for metal-arc welding. *Weldwire*

24. Aluminum Castings
Brochure "How To Cut Die-Casting Finishing Costs" deals with aluminum castings. *Monarch Aluminum*

25. Aluminum Extrusions
Data on services in the field of aluminum extrusions. *Himmel Bros Co.*

26. Aluminum Melting
8-page Notes on Aluminum deals with protecting molten aluminum, degassing and grain refining. *Foundry Services*

27. Aluminum Melting
Folder A-5 describes automatic melting and pouring unit for production of aluminum die castings. *Ajax Eng'g.*

28. Ammonia Dissociators
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

29. Ammonia for Heat Treat
Booklets available on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "The Nitriding Process" and "Carbonitriding". *Armour*

30. Analysis
Bulletin 390-1 on 8-min. copper assay with electro-analyzer. *Eberbach Corp.*

31. Annealing
Booklet on burner for annealing and other uses where flame impingement is not permissible. *Bloom Engineering*

32. Atmosphere Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

33. Atmosphere Furnace
Illustrated bulletin describes new controlled atmosphere furnace. *Industrial Heating Equipment Co.*

34. Atmosphere Furnaces
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

35. Atmosphere Furnaces
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

36. Atmosphere Generators
12-page booklet on gas producers describes equipment and gives data on composition and applications of atmospheres. *Bellevue Industrial Furnace*

37. Atom Models
12-page booklet on construction of scale models of atomic crystal structures. *Fisher Scientific*

38. Barrel Finishing
22-page book gives facts and figures on barrel finishing, tells how single-unit installation may yield savings up to 95% on various parts. *Almco Div.*

39. Barrel Plating
Folder describes equipment for barrel plating with unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply*

40. Bending
Presses for bending, forming, blanking, drawing and multipunching are described in catalog 2010. *Cleveland Crane & Engineering*

41. Boron Nitride
Data Sheet 513B on properties and possible uses of boron nitride. *Norton Co.*

42. Brazing
Article on furnace brazing at Modine Mfg. Co. *Sunbeam*

43. Brazing
Bulletin 124 — on salt bath brazing process — shows how it is possible to substitute brass for copper and develop joints of adequate strength for most steel assemblies. *Ajax Electric*

44. Brazing-Alloy Washers
Free sample of silver brazing-alloy preformed washer coined from wire. *Lucas-Milhaupt Engineering*

45. Bronze, Continuous Cast
12-page bulletin on applications, properties, weights of continuous cast bronze rods, tubes, shapes. *American Smelting & Refining*

46. Burner
Bulletin on new gas-oil blast burner *Eclipse*

47. Burners
Bulletin on combination gas and oil burner with high rate of combustion. *Ra-Diant Products*

48. Burners
16-page bulletin for selection of gas burners. *Western Products*

128. Heat Treating Stainless Steel

Heat treating stainless steels – theory and practice – is the subject of one of the newest additions to the manufacturers' literature.* This generously illustrated 84-page booklet is, of course, primarily devoted to the "400 Series" of chromium stainless steels but also includes information on annealing cycles and properties of chromium-nickel austenitic types.

The opening discussion explains the transformation characteristics of chromium stainless steels which are taken advantage of in hardening the ferritic grades. Time-temperature-transformation diagrams ("S-curves") are shown.

The theory in the first section is translated into practical shop procedure in the second section of the booklet. Specific treatment temperatures and times for the various types of chromium stainless are presented. In the section on shop methods of annealing and pickling, specific treatments are likewise given in detail for both ferritic and austenitic types of stainless.

Representative properties developed by heat treating the hardenable stainless steels are presented in a series of 14 charts. These charts show the variation in strength, proportional limit, reduction of area, elongation, and impact strength – with tempering temperature for all types of chromium stainless. Representative values can be picked off the charts with ease.

The booklet closes with a presentation of a series of simple tests for use in identifying the various grades of stainless should they become mixed or otherwise lose their identity, and with an assembly of tables giving physical, mechanical and fabricating properties of all types of stainless steel.

*Published by Republic Steel Corp. Copies are available at no charge to readers of Metal Progress who circle No. 128 on the literature request card, page 32B.

49. Carbide
Brochure describes sintered chromium carbide for gage blocks. *Firth Sterling*

50. Carbon Control
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup*

51. Carbon and Graphite
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical and process fields. *National Carbon*

52. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

53. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

54. Carburizer-Nitrider
28-page Bulletin 646 on electric carburizing and nitriding furnace giving

atmosphere circulation up to 1850° F. *Hevi Duty Electric*

55. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

56. Centrifugal Castings
12-page bulletin on steel shapes made by centrifugal casting in metal mold. *Lebanon Steel Foundry*

57. Chromium Cast Iron
"Abrasion-Resistant High-Chromium Iron" on how to make and use abrasion-resistant iron castings efficiently. *Electro Metallurgical*

58. Chromium Plating
"How to Chromium Plate 20 to 80% Faster" describes self-regulating high-speed bath. *United Chromium*

59. Chromium Stainless
Folder on uses of chromium stainless steels; table of analyses and properties. *Lebanon Steel Foundry*

60. Clean Hardening
Bulletin describes clean hardening of steering arms and lever shafts at Ross Gear & Tool. *Surface Combustion*

61. Cleaner and Phosphatizer
Literature on Divobond, a mildly acid compound which cleans and phosphatizes iron and steel in a single spray operation. *Diversey*

62. Cleaning
Pamphlet on properties and use of trichloroethylene. *Niagara Alkali*

63. Cleaning
6-page bulletin includes concentrations for various metal cleaning applications and a handy list of cleaners for general industrial use. *E. F. Houghton*

64. Cleaning
12-page Bulletin 68 deals with factors to consider in selecting metal cleaning equipment. *Despatch Oven*

65. Cleaning Equipment
Vapor degreaser described and diagramed in folder. Data on different models. *Topper Equipment*

66. Cleaning and Finishing
Catalog A-653 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

67. Cold Cleaners
Bulletin on two new metal cleaners for use at room temperature in power washers. *E. F. Houghton*

68. Cold Finished Bars
Engineering bulletin, "New Economies in the Use of Steel Bars". *LaSalle Steel*

69. Cold Heading Brass Wire
"Cold Heading Extruded Brass and Copper Wire" gives physical and fabrication properties, applications, lb. per 1000 ft. and ft. per lb. *Chase Brass*

70. Cold Steel Extrusion
Bulletin on commercial applications of company's Koldflo process for steel. *Mullins Mfg. Co.*

71. Cold Work Die Steel
24-page catalog on die steels for cold work. Machinability, hardenability, dimensional stability, wearability. *Vanadium-Alloys Steel*

72. Core Binders
8-page book on resins for use as core binders. *American Cyanamid*

73. Corrosion Protection
23-page bulletin on Bonderite, corrosion resistant paint base. *Parker Rust Proof*

74. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

75. Cutting Compounds
Data on cutting compounds for stainless and titanium. *Hangsterfer's Labs.*

76. Cutting Fluids
"More Than a Coolant Is Needed" is new booklet describing cutting fluids and lubricants. *D. A. Stuart*

77. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service Oil*

78. Cutting Oil
New pamphlet on sulphurized oil applicable to stainless steel and more easily machined alloys. *Gulf Oil*

79. Deburring
Bulletin on deburring and other barrel finishing operations. *Magnus Chemical*

80. Design of Dies
32-page bulletin on design of dies for upset forging. Also rules for upsetting and examples of forgings. *Ajax Mfg.*

81. Dew-Point Recorder
Bulletin 407 and Data Sheet AED 340-7 on dew-point systems for recording or controlling. *Foxboro*

82. Edge Position Control
4-page Bulletin 141 on method for controlling edge position of a moving strip of metal or other material. *Askania Regulator*

83. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

84. Electric Furnaces
Bulletin 473 on automatic melting machine for ferrous and nonferrous alloys. *Detroit Electric Furnace*

85. Electric Melting
Series of three bulletins on induction furnaces for melting ferrous and nonferrous metals. Data on capacity and power consumption for different alloys. *Russ Electric Furnace*

86. Fabricating Machinery
16-page technical bulletin on special-purpose metalworking machinery for ferrous and nonferrous metals. *H. W. North Co.*

87. Finishes
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

88. Finishing Systems
Bulletin on cleaning and rust proofing equipment, spray booths and drying ovens. *Peters-Dalton*

89. Flow Control
24-page Bulletin 139 on controls for pressure and flow of liquids and gases. Details on proportioning control. *Askania Regulator*

90. Flow Meters
Catalog C-12 describes meters and accessories for measuring pressure, vacuum and differential pressure of liquids and gases. *Meriam Instrument*

91. Flux, Aluminum Melting
Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals & Metals*

92. Forge Heating
Bulletin 1081 on high thermal release burner unit for quick heating and intense concentration of heat. *Bloom*

93. Forgings
New booklet on smooth hammered forgings of alloy, stainless and tool steel. *Allegheny Ludlum*

94. Forming
86-page book on equipment and process of cold roll-forming. Wide sheets, narrow trim, tubular shapes, curving, coiling, tooling needed. *Yoder*

95. Forming Dies
Data sheet gives information on roller dies for forming tubes, pipe and cold rolled shapes. For all roll forming machines. *American Roller Die*

96. Foundry Control
Bulletin 330-6 gives data on air weight controller for foundry cupolas. *Foxboro*

97. Foundry Practice
Article discusses fume control in brass foundry. *R. Lavin & Sons*

98. Furnace Fixtures
16-page Catalog 16 on baskets, trays, fixtures, retorts and carburizing boxes for heat treating and quenching; 66 designs. *Stanwood Corp.*

99. Furnace Maintenance
"Maintenance Guide for Electric Heat Treating Furnaces" describes preventive program. *Hevi Duty Electric*

100. Furnaces
Bulletin 435 describes new furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

101. Furnaces
44-page Catalog 112, well illustrated, features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

102. Furnaces
Bulletin on furnaces for annealing, normalizing, hardening, tempering, forging. *Flinn & Dreffein Engineering*

103. Furnaces
6-page folder describes 18 typical installations of gas-fired and electric furnaces. Equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

104. Furnaces
Bulletin B-90 on electric and fuel fired roller-hearth furnaces for heat treating. Atmosphere generators included. *Drever*

105. Furnaces
High temperature furnaces for temperatures up to 2000° F. are described in leaflet. *Carl-Mayer Corp.*

106. Furnaces
Catalog on electric furnaces for tool room and general-purpose heat treating; also 600° F. ovens. *Cooley Electric*

107. Furnaces, Atmosphere
Bulletin F-1 on versatile, controlled-atmosphere furnace for all steels from high carbon to high speed in range 1200 to 2800° F. *Delaware Tool Steel*

108. Furnaces, Laboratory
26-page "Construction of Laboratory Furnaces" contains many diagrams, charts, tables, and information on how to construct furnaces. *Norton Co.*

109. Furnaces, Rotary Hearth
Folder giving drawings, dimensions, capacity, Btu required for drawing, annealing, forging. *Gas Machinery*

110. Furnaces, Small Tool
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

111. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

112. Hand Pyrometer
Data sheet GEC-836 on hand pyrometer with scale ranges of 0 to 500 and 0 to 1500° F. *General Electric*

113. Hard Facing
Bulletin on spraywelder for use in hard facing. *Wall Colmonoy*

114. Hardness Tester
Circular on portable hardness tester in sizes for work 1 to 6 inches round and flat. *Ames Precision*

115. Hardness Tester
4-page bulletin on Brinell hardness tester weighing 26 lbs. for portable and stationary use. *Andrew King*

116. Hardening Stainless
24-page "Story of Malcomizing" describes surface hardening of stainless steels. *Lindberg Steel Treating Co.*

117. Heat Processing
12-page Bulletin S-7.1 on basic engineering requirements of heat processing with radiant gas. *Selas*

118. Heat Resistant Gloves
12-page catalog of heat and flame resistant gloves for heat treating and welding operators. *C. Walker Jones Co.*

119. Heat-Resisting Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion to 2000° F. *Chicago Steel Foundry*

120. Heat Treating
Booklet describes facilities for heat treating steel, aluminum and magnesium. *Pearson Industrial Steel Treating*

121. Heat Treating
Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam*

122. Heat Treating
Bulletin T-19 on forced convection furnaces for heat treating in controlled atmosphere. *Ipsen*

123. Heat Treating Ammonia
"Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div., Allied Chemical & Dye Corp.*

124. Heat Treating Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

125. Heat Treating Fixtures
24-page catalog B-8 on muffles, retorts, baskets, and many other fixtures for heat treating in gas or salt baths. *Rolock*

126. Heat Treating Fixtures
Extensive catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

127. Heat Treating Furnaces
Bulletin on gas, oil and electric furnaces of box and pot types for heat treating. *Dempsey Industrial Furnace*

128. Heat Treating Stainless
See review on page 27. *Republic Steel*

129. Heating Equipment
Bulletin, "Make Your Own Gas", describes generator to convert oil to gas for standby or primary fuel. *Vapofier*

130. Heating for Brazing and Annealing
8-page, illustrated bulletin on high speed heating equipment for brazing, flame annealing, flame hardening, selective heating, and heating for forming. *Gas Appliance Service, Inc.*

131. High-Alloy Castings
New 28-page 3rd edition of "Nickel-Chrome Castings to Resist Heat & Corrosion". *Standard Alloy*

132. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

133. High-Temperature Alloy
Data sheet on wrought alloy type 330, 35% Ni – 15% Cr. Mechanical properties

of bars to 1800° F.; design stresses to 2100° F. *Michigan Steel Casting Co.*

134. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite*

135. Identifying Alloys
Booklet of procedures for rapid identification of more than 125 metals and alloys. *International Nickel*

136. Identifying Stainless
Cardboard chart outlining systematic method for rapid identification of unknown or mixed stocks of stainless steels. *Carpenter Steel*

137. Impact Forming
16-page bulletin on new process for automatic mechanical production of impact die forgings. *Chambersburg Eng'g.*

138. Induction Heat Control
Sheet 83 on miniature radiation-detecting temperature-measuring device for flame hardening and induction heating. *Minneapolis-Honeywell*

139. Induction Heating
"Induction Heating and Melting" contains selector chart and table of heating and melting speeds for standard induction equipment. *Ajax Electrothermic*

140. Induction Heating
12-page bulletin 5679 on equipment for induction hardening, brazing, and annealing at 1000, 3000 and 10,000 cycles. *General Electric*

141. Induction Heating
Bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forging, extrusion and rolling. *Loftus Eng'g.*

142. Induction Heating
Data folder on megacycle tube-type machines for soldering, brazing, hardening. *Sherman Industrial Electronics*

143. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

144. Lockseam Tubing
Blueprint of size ranges of round or oval lockseam tubing in a wide range of metals. *H & H Tube and Mfg.*

145. Low-Temperature Tests
Bulletin MC-1 on cryostat that maintains a test chamber from room temperature to within 2° of absolute zero. *Arthur D. Little*

146. Low-Temperature Tests
62-page bulletin on equipment for low-temperature tests. *Bowser Technical Refrigeration*

147. Lubricant
Uses of colloidal graphite for hot metalworking operations (deep piercing, forging, stretch forming and wire drawing operations). *Acheson Colloids*

148. Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

149. Machining Alloy Steels
24-page bulletin on economical combination of microstructure, tool form, cutting speed and feed for each machining operation. *International Nickel*

150. Machining Copper Alloys
32-page booklet gives cutting speeds, feeds, rakes, clearances for more than 40 copper alloys. *American Brass Co.*

151. Machining of Stainless
Bulletin on high production machining on stainless steel valve parts. *Cooper Alloy Foundry*

152. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

153. Magnesium Melting
Bulletin on use of fabricated steel crucibles in melting of magnesium alloys. *American Tank & Fabricating*

154. Melting Aluminum
Bulletin 310 on gas and oil-fired furnaces for melting aluminum. *Lindberg Engineering*

155. Metal Cutting
64-page catalog No. 28 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

156. Metallograph
Revision of catalog includes the new metallograph with polarizing and phase attachments. *American Optical*

157. Metallurgical Apparatus
200-page catalog of metallurgical apparatus: cutters, grinders, mounting presses, polishers, metallographs, microscopes, cameras, testing machines, analytical apparatus, spectrographs, furnaces, accessories and supplies, and 250 recommended metallurgical books. *Buehler Ltd.*

158. Microhardness Tester
Bulletin DH-114 on Tukon hardness testers in research and industrial testing. *Wilson Mechanical Instrument*

159. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

160. Nickel Cast Iron
Booklets entitled "Engineering Properties and Applications of Ni-Resist", and "Buyers' Guide for Ni-Resist Castings". *International Nickel*

161. Nondestructive Testing
Data on electronic inspection equipment and comparators for sorting. *Magnetic Analysis*

162. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

163. Phosphate Coating
12-page "Phosphate Coating Chemicals and Processes" gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

164. Pickling Acid Inhibitor
Selection chart tabulates properties and uses of 15 types of Rodine pickling acid inhibitor. *American Chemical Paint*

165. Pickling Baskets
Information on baskets for degreasing, pickling, anodizing and plating. *C. O. Jelliff*

166. Photography
Catalog, "Kodak Sensitized Materials for the Scientific and Industrial Laboratory", tells of special films, plates and pellicles, transmission curves of filters and filter combinations commonly used in photography. *Eastman Kodak*

167. Plating Racks
8-page booklet offers data on a plating rack designed to make the spline section or body of the plating rack a permanent tool. *National Rack*

168. Powder Metallurgy
"A Short Cut to Production of Powder Metal Parts". *Metachem Laboratories*

169. Powder Metallurgy
6-page bulletin gives recommended design procedures on powder metal parts from ferrous and nonferrous metals. *American Sintered Alloys*

170. Powder Metallurgy
Information on sponge iron powder. *Ekstrand & Tholand*

171. Precision Casting
8-page bulletin on investment castings of ferrous and nonferrous alloys. *Engineered Precision Casting*

172. Precision Casting
12-page illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields. *Alexander Saunders & Co.*

173. Precision Castings
Bulletin 706 on the Mercast frozen mercury process of investment casting. *Alloy Precision Castings*

174. Pre-Plated Metals
16-page fabrication handbook on pre-plated metals, ferrous and nonferrous. *American Nickeloid*

175. Pyrometer Supplies
Buyers' Guide for pyrometer supplies, No. 100-4. *Minneapolis-Honeywell*

176. Quenching
8-page bulletin on continuous quench tank conveyor. *Klaas Machine & Mfg.*

177. Quenching
"Handbook on Quenching" gives complete information. *E. F. Houghton*

178. Quenching Holes
Bulletin on new machine for quenching die holes in case hardening. *Palmer Mfg.*

179. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil*

180. Rapid Carbon Analysis
Literature on complete line of rapid carbon analyzers for steel, cast iron, pig iron, coal, coke and oil. *Laboratory Equipment Corp.*

181. Recorder Controllers
48-page catalog ND 46(1) gives specifications, numerous installation pictures of recorders and controllers for temperature, stress, strain and other variables. *Leeds & Northrup*

182. Refractories
20-page booklet gives technical information on super refractories. Charts, tables and application data. *Refractories Div., Carborundum Co.*

183. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for services to 3000° F. *Johns-Manville*

184. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

185. Reverse-Current Cleaner
Bulletin on electrocleaner 12 for steel, copper and brass with either reverse or direct current. *Diversey*

186. Safety Valves
Bulletin 400 describes safety valves for instantaneously shutting off fuel in case of power failure to some essential unit. *Western Products*

187. Salt Bath Furnaces
Illustrated folders give data on salt bath furnaces for batch and conveyorized work. *Upton Electric Furnace*

188. Sawing Refractorie
Illustrated folder describing masonry saw for shaping re bricks. Pictures of nine differen and number of seconds require each shape. *Clipper Manufactu*

189. Sheet Metal Testin
8-page folder on equipment ing the drawing, stamping, com and folding qualities of sheet a *J. Arthur Deakin*

190. Shot Peening
Catalog describes selection a shot and grit for cleaning and *Cleveland Metal Abrasive*

191. Silver Brazing Flux
Bulletin T-8 on use of fluxes alloy brazing. *Handy & Harm*

192. Soldering Equipme
8-page brochure on solder brazing equipment describes ne soldering gun and shows its app to production-line soldering a ing. *Metallizing Co. of Americ*

193. Sonic Thickness T
Bulletin on measurement wall thickness from one side method. *Branson Instruments*

194. Specification Key
Guide to Government spec for phosphatizing, rust proo paint bonding chemicals. *Chemical Paint*

195. Specimen Grinders
6-page booklet describes grin surfacers for metallurgical both belt and wheel types fo dry grinding. *Buehler Ltd.*

196. Specimen Mount P
Bulletin describes press featu heated premolds, rapid closing versal application for thermos thermoplastic materials in th *Buehler Ltd.*

197. Spectrophotomete
Bulletin B-211 on junior-siz photometer for identifying a uring solution constituents. *H*

198. Stainless Castings
48-page Catalog 52 on com of stainless valves, fittings, a Engineering data, sizes, corr sults. *Cooper Alloy Foundry*

199. Stainless Steel
44-page book gives detailed tion on use of stainless ste chemical industries. *Crucible*

200. Stainless, Type 43
12-page book on fabrication of Type 430 stainless steel. *Sha*

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brication and use teel. *Sharon Steel*

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(Sec. 34.9 P.L. & R.)
Cleveland, Ohio

201. Steels, Spring
Spring steel catalog offers 785 sizes of hardened and tempered spring steels, and 133 cold-rolled and bright annealed sizes in stock. *Sandvik Steel*

202. Straightening Bars
Catalog describes two-roll rotary straightener for round tubes and bars 1/16 to 3/16 in. O.D. *Medart Co.*

203. Subzero Chest
Data on chest for use down to −95° F. for production use and testing. *Revco*

204. Subzero Freezer
8-page folder on portable freezer, 110-volt a.c., operating to −180° F., for shrink fitting, hardening, stabilizing and testing. *Webber Appliance*

205. Surface Pyrometer
Bulletin 168 on all-purpose instrument for quick, accurate readings of surface and subsurface temperatures. *Pyrometer Instrument*

206. Surface Temperatures
Pyrocon bulletin on hand-held thermocouple-type instrument for measuring and indicating surface temperatures at exact locations. *Illinois Testing Labs.*

207. Subzero Treatment
Advantages of low-temperature metal treatment are described in a new 8-page folder. Processes covered are for stabilization, increasing tool life and shrink-fit assembly. *Sub-Zero Products*

208. Tanks and Linings
16 pages of data on tanks and corrosion-resistant linings for cleaning and plating solutions. *Chemical Corp.*

209. Temperature Control
Catalog of pyrometer supplies gives data on thermocouples, protection tubes, other accessories. *Arklay S. Richards*

210. Temperature Control
36-page bulletin P 1245 on new electronic instruments for recording and indicating variables. *Bristol Co.*

211. Tempering
Reprint of article on controlled atmosphere tempering. *Ipsen*

212. Test Accessories
22-page Bulletin 46 on instrumentation, tools and accessories for mechanical testing machines. *Tinius Olsen*

213. Testing
Booklet on Reflectoscope tells how ultrasonic vibrations penetrate up to 24 feet to "see" internal defects and fatigue cracks. *Sperry Products*

214. Testing Machines
28-page catalog on screw power universal testing machines and accessories. Details of construction and specifications. *Riehle*

215. Testing Machines
Universal testing machines and equipment are diagramed, described and illustrated in 20-page Bulletin 43. *Tinius Olsen*

216. Textured Stainless
6-page folder on suggested uses for stainless metals to conserve strategic alloys and reduce weight. *Rigidized*

217. Thermocouple Data
42-page Bulletin TC-9 on thermocouples, radiation detectors, resistance bulbs, accessories. *Wheelco*

218. Thermocouples
44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. Tabular data on accuracy and limits of couples. *Leeds & Northrup*

219. Thickness Gaging
28-page bulletin on continuous gages and controls for thickness and width of sheet, foil and wire. *Pratt & Whitney*

220. Tin
Monthly newsletter, "Tin News", gives information about rises, supply, demand. *Malayan Tin Bureau*

221. Tong Ammeters
Bulletin on tong test ammeters, a.c. or d.c., for instant current measurements without breaking circuit or touching conductor. *Columbia Electric*

222. Tool and Die Steels
Revised edition of "Matched Tool and Die Steel Manual" deals with selection, heat treating and uses of tool steels. *Carpenter Steel*

223. Tool and Die Steels
26-page book on six oil and air hardening steels for high-production tools and dies. Many uses illustrated. *Bethlehem Steel*

224. Tool Furnace
17-page Bulletin 1054 on tool hardening equipment. *Sentry*

225. Tool Sharpening
Case histories on increase in tool life through control of surface roughness. *Micrometrical Mfg.*

226. Tool Steel Heat Treat
Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

227. Tool Steel Selector
Selector is handy chart featuring general and heat treating data on nondeforming, water hardening, shock-resistant, hot work, high speed tool and hollow die steels. *A. Milne & Co.*

228. Tool Steels
Stock list of available tool and die steels. *Reliable Steel*

229. Tubes and Bars, Steel
New stock list on 52100 tubing, bars, and ring forgings. *Peterson Steels*

230. Tubing
12-page technical data book on brazed steel tubing made from copper-coated steel. *Bundy Tubing*

231. Turbo Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

232. Welding Armor Plate
Booklet discusses new low-hydrogen ferritic electrodes for welding armored ships and tanks. *Arcos Corp.*

233. Welding Electrodes
Application chart for stainless, alloy and nonferrous electrodes. *Weldwire*

234. Welding Equipment
Cadwell process and complete list of arc-welding accessories are described in catalog. *Erico Products, Inc.*

235. Welding Magnesium
Article on inert-gas-shielded metal-arc welding of magnesium includes numerous illustrations and tables of data. *Dow Chemical*

236. Welding Pressure Vessels
Reprint describes procedures for welding stainless, stainless-clad and copper alloy pressure vessels and refinery components. *Air Reduction*

237. Weld-Rod Stabilizer
4-page bulletin on low-hydrogen electrode stabilizer. Includes complete specifications of company's equipment for dehydrating mineral shielding or low-hydrogen electrodes. *Fred C. Archer*

238. Wire Mesh Belts
Manual includes useful data on conveyor design, metallurgical tables and belt specifications. *Cambridge Wire Cloth*

239. Wire Straightening
Bulletin 52-C describes precision machine for straightening small wire with extreme accuracy. Applies to round wire 0.007 to 0.125 in. diameter of ferrous or nonferrous metal. *Medart Co.*

240. X-Ray Accessories
72-page catalog on film-processing tanks and systems, darkroom accessories, X-ray protection materials. *Bar-Ray Products*

241. Zinc and Cadmium Plate
Technical data sheets on use of Luster-on salts for zinc and cadmium plating. *Chemical Corp.*

January, 1953

1	26	51	76	101	126	151	176	201	226
2	27	52	77	102	127	152	177	202	227
3	28	53	78	103	128	153	178	203	228
4	29	54	79	104	129	154	179	204	229
5	30	55	80	105	130	155	180	205	230
6	31	56	81	106	131	156	181	206	231
7	32	57	82	107	132	157	182	207	232
8	33	58	83	108	133	158	183	208	233
9	34	59	84	109	134	159	184	209	234
10	35	60	85	110	135	160	185	210	235
11	36	61	86	111	136	161	186	211	236
12	37	62	87	112	137	162	187	212	237
13	38	63	88	113	138	163	188	213	238
14	39	64	89	114	139	164	189	214	239
15	40	65	90	115	140	165	190	215	240
16	41	66	91	116	141	166	191	216	241
17	42	67	92	117	142	167	192	217	
18	43	68	93	118	143	168	193	218	
19	44	69	94	119	144	169	194	219	
20	45	70	95	120	145	170	195	220	
21	46	71	96	121	146	171	196	221	
22	47	72	97	122	147	172	197	222	
23	48	73	98	123	148	173	198	223	
24	49	74	99	124	149	174	199	224	
25	50	75	100	125	150	175	200	225	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name ____________________

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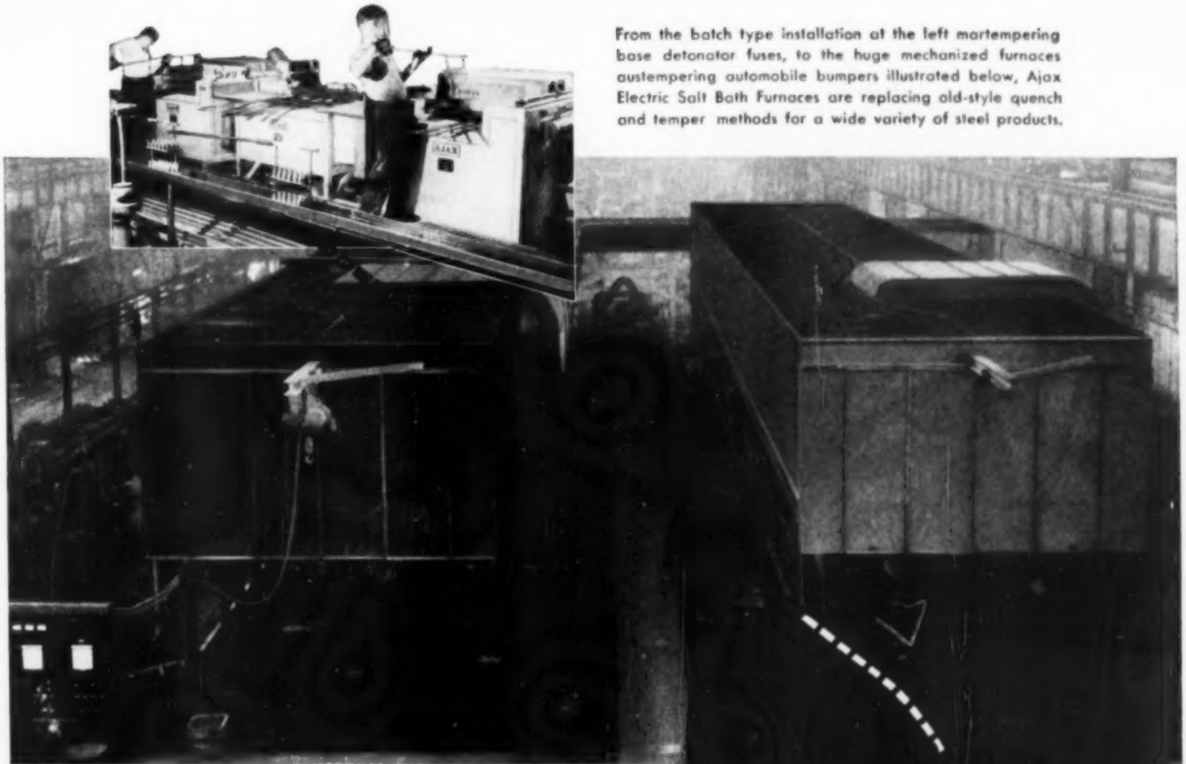
Postcard must be mailed prior to April 1, 1953—
Students should write direct to manufacturers.



From the batch type installation at the left martempering base detonator fuses, to the huge mechanized furnaces austempering automobile bumpers illustrated below, Ajax Electric Salt Bath Furnaces are replacing old-style quench and temper methods for a wide variety of steel products.

From ring gears to plow points . . .

From bearing races to cast iron cylinder sleeves . . .

From uniformly shaped metal parts to odd and irregular sizes . . .

Scores of installations have proved the tremendous possibilities for economy, greater speed and efficiency in martempering and austempering, because all water and oil quenches are eliminated.

Distortion is so negligible that parts can be machine finished *before* hardening. Final grinding is eliminated or materially reduced. Scale, decarb and quench cracks are eliminated. Toughness and ductility are increased. The work is done materially faster—in less floor space—with lower labor costs. Let the Ajax Metallurgical Service Laboratory prove these claims on a specimen batch of your actual parts, under actual working conditions.

Write for Ajax Bulletin 120

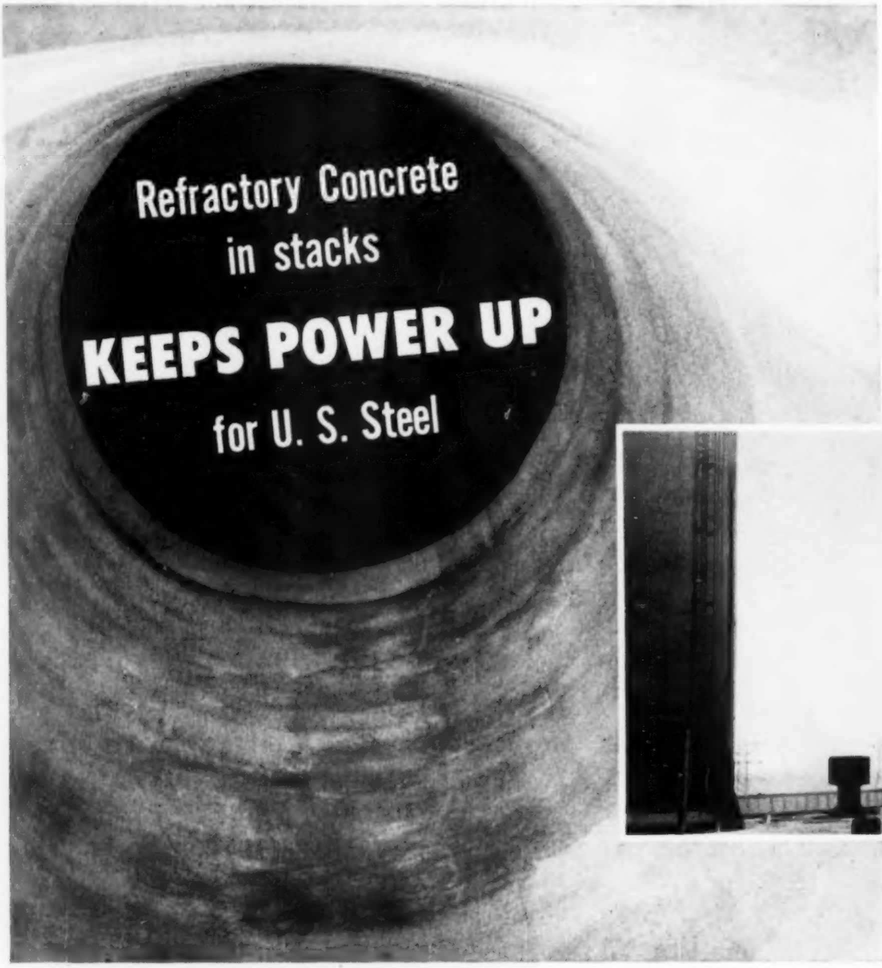
AJAX ELECTRIC COMPANY, INC.

910 Frankford Avenue

Philadelphia 23, Penna.

World's largest manufacturer of electric heat treating furnaces exclusively

AJAX ELECTRIC SALT BATH FURNACES



FAST WORK—Each 14′ 10″ i.d. x 61′ 6″ high stack got a 2½″ lining of Refractory Concrete in just 4 days after reinforcing wire mesh was attached. Concrete made with Lumnite Cement and traprock was "shot" on by cement gun

You're looking down

the smooth, jointless Refractory Concrete lining that protects a power stack at the new Fairless Works. It's the way U. S. Steel assures long, trouble-free stack life. Here's why:

Saves time. Fast, monolithic construction is further speeded by the ability of Refractory Concrete made with Lumnite* Cement to reach service strength in 24 hours or less! *Helps draft.* The one-piece lining prevents "breathing." *Gives long-lasting protection.* Lumnite-made Refractory Concrete resists attack of sulphurous gas and abrasive fly ash, takes heat to 2600°F, has low volume change and withstands thermal shock.

Whether you're lining or rebuilding a stack, it will pay you to look into the enviable record of Refractory Concrete made with Lumnite calcium-aluminate cement—in power, metals and refining industries . . . in fact, wherever heat, corrosion or abrasion are problems.

FOR CONVENIENCE, you may prefer to make Refractory Concrete with prepared castables (Lumnite Cement plus aggregates selected for specific temperature and insulation service—add only water). They're made by refractory manufacturers and sold through their dealers. For more information, write Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N. Y.

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

MP-L-71

ATLAS® LUMNITE for INDUSTRIAL CONCRETES

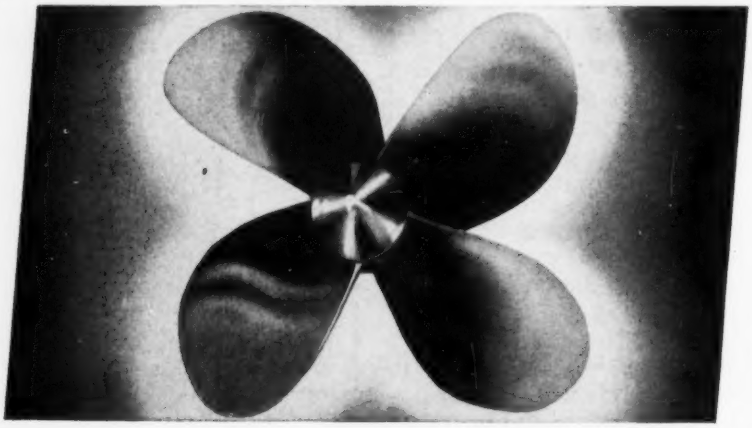
REFRACTORY, INSULATING, OVERNIGHT, CORROSION-RESISTANT

A UNIVERSAL ATLAS PRODUCT

"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries — Sunday Evenings — NBC Network*

WHY *Manganese Bronze* CAN BETTER SERVE YOUR NEEDS . . .

HIGH STRENGTH PLUS RESISTANCE TO CORROSION



MANGANESE BRONZE HAS HIGH STRENGTH AND GOOD ELONGATION IN THE "AS CAST" CONDITION . . .

Because of their unusual combination of high strength and corrosion resistance coupled with good ductility and hardness these alloys have many varied applications, among which are valve stems, marine castings and fittings, pump bodies, gears and bearings.

The "As Cast" tensile strength of Manganese Bronze alloys ranges from 60,000 to 110,000 P.S.I. Competitive copper alloys usually require heat treatment to develop the same strength thereby adding to the cost.

FREE . . . Write for your copy of the 8-page Lavingot Technical Journal — Vol. 8, No. 4 containing an article discussing "Fume Control in the Brass Foundry."

Specify—LAVIN NONFERROUS INGOT—*Quality*

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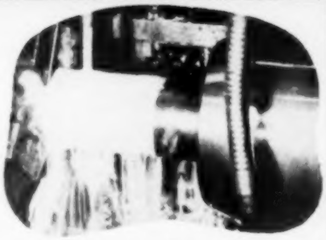
REPRESENTATIVES IN PRINCIPAL CITIES

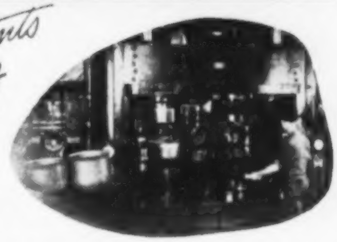
New Processing Aids in the Houghton Line

coolants and lubricants for MACHINING



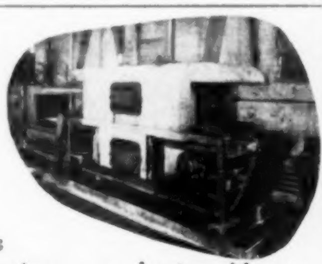
☐ Want a single water soluble cutting base that will handle 90% of all machining jobs?

drawing lubricants for FORMING



☐ Like the latest data on compounds that ease the draw and simplify today's complex forming operations?

compounds for metal CLEANING

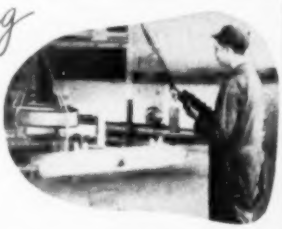


☐ How about a "cold cleaner" that is used at room temperature . . . no heat problems, freedom from rusting, savings all along the line?

core oils for CASTING

☐ Are you looking for a surer way to choose the *right* core-oil-to-sand combination in your foundry operations?

salts and quenching oils for HEAT TREATING



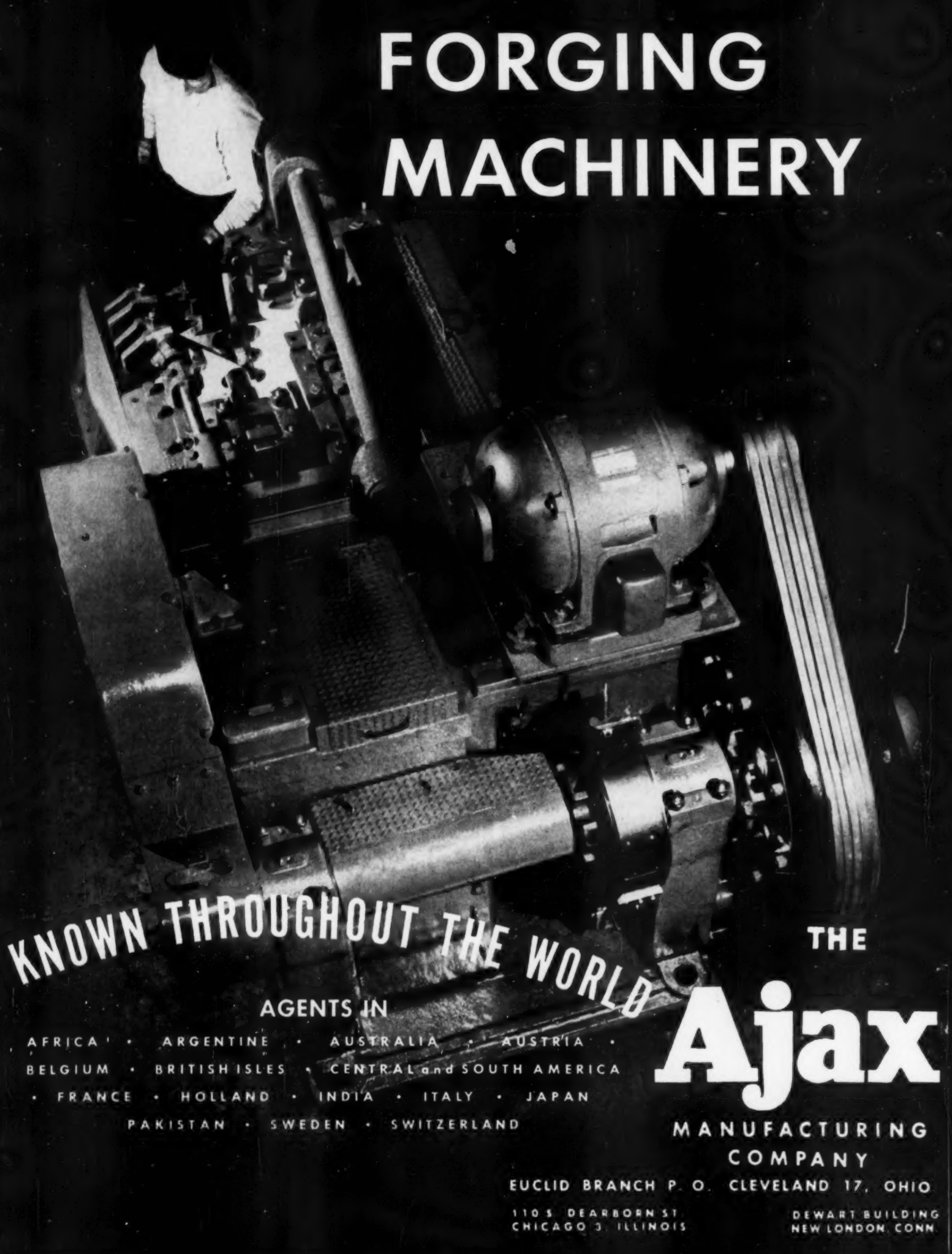
☐ How about a quenching oil faster in quenching speed than any oil medium yet developed for lean alloy steels?

inhibited coatings for RUST PREVENTION

☐ Or one thin-film multi-purpose rust preventive that's the answer to most of your rust prevention problems?

E. F. HOUGHTON & CO.

PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO



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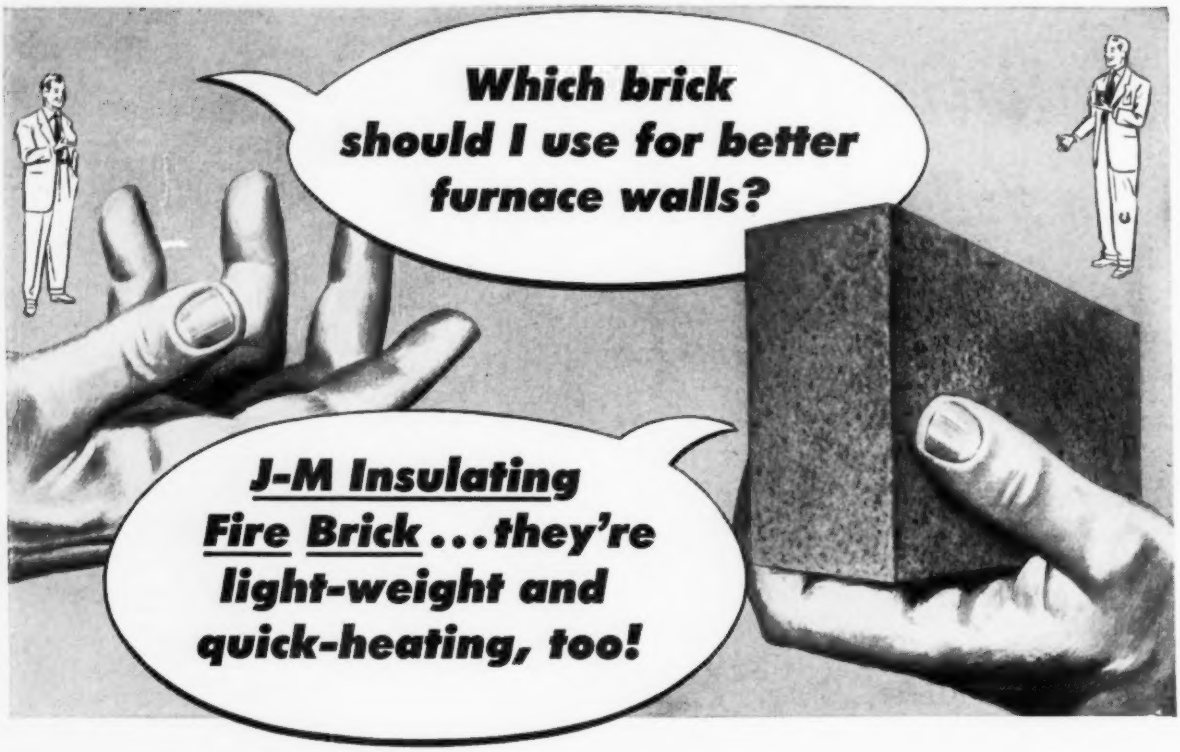


6 types . . . for savings in services up to 3000F

Because of their quick-heating and low-heat transfer characteristics, Johns-Manville Insulating Fire Brick are efficient fuel-savers for use at operating temperatures up to a full 3000F on the insulation.

Each type of J-M Insulating Fire Brick has the correct balance of thermal and physical properties that assures maximum economies within a specific temperature range. All types are *quick-heating* . . . operating temperatures are reached in a short time, thereby saving fuel.

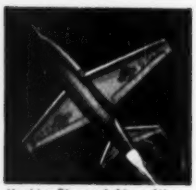
Identical materials can also be obtained in large size units known as Johns-Manville Insulating Fireblok. Fireblok have the same properties as the brick, but are made in extra large sizes for added construction economies. The large units can be installed faster . . . require fewer joints and less bonding mortar. During rebuilding or repair, furnace down-time is appreciably shortened with Fireblok construction.

A Johns-Manville insulation expert will gladly explain the advantages and economies of using J-M Insulating Fire Brick and Fireblok for refractory linings or as back-up insulation behind other refractory protection. Write to Johns-Manville, Box 60, New York 16, N. Y. In Canada, write 199 Bay St., Toronto 1, Ontario.

Properties	Types of Insulating Fire Brick and Fireblok					
	JM-3000	JM-28	JM-26	JM-23	JM-20	JM-1620
Temperature limit	†3000F	†2800F	†2600F	†2300F	†2000F	‡2000F †1600F
Density, lb per cu ft	63–67	58	48	42	35	29
Transverse strength, psi	130	120	125	120	80	60
Cold crushing strength, psi	400	150	190	170	115	70
Linear shrinkage, percent	*0.8 at 3000F	4.0 at 2800F	1.0 at 2600F	0.3 at 2300F	0.0 at 2000F	0.0 at 2000F
Reversible thermal expansion, percent	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F	0.5–0.6 at 2000F
Conductivity (Btu in. per sq ft per F per hr at following mean temperatures)						
500F	3.10	2.00	1.92	1.51	0.97	0.77
1000F	3.20	2.50	2.22	1.91	1.22	1.02
1500F	3.35	3.00	2.52	2.31	1.47	1.27
2000F	3.60	3.50	2.82	2.70	....	....

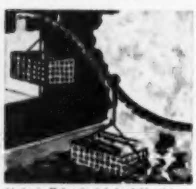
*24-hr Simulative Service Panel Test; all others 24-hr soaking period. †Back-up or exposed. ‡Back-up only.

JOHNS-MANVILLE JM PRODUCTS **Johns-Manville** *first in* **INSULATIONS**



Hoskins Chromel-Alumel thermocouple alloys accurately register exhaust temperatures of jet aircraft engines.

Heating elements made of Hoskins Chromel give long life service in industrial electric furnaces, home appliances.



Hot stuff for hot jobs! Hoskins Alloy 502 is widely used by industry for many heat resistant mechanical applications.

You're looking in on a life-saving operation . . . one that's being performed on an engine valve. Not an ordinary valve for an ordinary engine. But a valve destined for long, hard service in an aircraft, tank, or heavy-duty truck engine. A valve that must be made to stand up under extremely severe operating conditions . . . high temperatures, for long periods of time, plus the destructive corrosive action of hot exhaust gases.

And what's responsible for long valve life under such gruelling conditions? Nothing less than Hoskins Alloy 717 . . . a closely controlled nickel-chromium composition developed especially for just such tough and vital service. It's highly resistant to heat . . . immune to the corrosive atmospheres created by combustion of high octane fuels. What's more, it's readily applied by fusion to form a non-porous protective facing over the basic valve forging.

But 717 is only one of several specialized nickel-chromium alloys developed and produced by Hoskins. Among the others: Alloy 502 . . . known throughout industry for its dependability on a wide range of heat resistant mechanical applications. The Chromel-Alumel thermocouple alloys . . . unconditionally guaranteed to register true temperature–E.M.F. values within specified close limits. Spark plug electrode alloys which have become universally accepted standards of quality and durability. And, of course, there's Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.

HOSKINS

MANUFACTURING COMPANY

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Chromel
NICKEL CHROMIUM WIRE

You can do this

better
cheaper
faster

IF THE METAL IS
Formbrite

Since The American Brass Company introduced Formbrite* as a superior drawing brass, scores of stamping shops, polishing and plating rooms throughout the country have changed their thinking.

Comparative tests prove conclusively that the superfine grain structure of this specially processed forming brass means stamped and formed products that are stronger, harder, "springier" and more scratch-resistant. Yet the metal is so ductile that it can be readily formed, drawn and embossed.

Timestudies made of finishing operations have shown that a bright, lustrous finish can be obtained by a simple "color buffing" operation in half the time previously required.

That's why we say you can do it *better, cheaper and faster* with Formbrite. Millions of pounds of Formbrite sheet and strip have been produced and economically fabricated into hundreds of different products. Want a sample—and more information? Address The American Brass Company, General Offices, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Limited, New Toronto, Ontario, Canada.

*Reg. U.S. Pat. Off.

In the pressroom of a supplier, the back of a military brush is blanked from Formbrite red brass strip.

Empire Brushes, Inc., Port Chester, N. Y. produces an extensive line of military and clothing brushes with Formbrite components. At right, a decorative band is being applied.

Formbrite
is an
ANACONDA PRODUCT
Made by The American Brass Company

...*when you LEAD them*, that's game in the BAG

You have to shoot *ahead* of fast-moving game, if you want to take home something for dinner. Same with business. Now's the time to plan for the day when you can get all the materials you want, with allocations gone, orders maybe not so plentiful, and competition red-hot. ● Allegheny Stainless Steel can work marvels in adding sales advantages to the products you make, or reducing operating costs in the equipment you use. Let our Development Engineers show you how.

Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pa.

AL
TIME-TESTED STAINLESS STEEL

You can make it *BETTER* with

Allegheny Metal

W&D 4098 B

Whether you need an oven for annealing, evaporating, heat treating, or sterilizing or a vacuum oven for dehydrating, the oven you get must be capable of maintaining the temperature required.

"Precision" freas ovens

Years of accurate, efficient, trouble-free service have proven the superiority of the Precision Freas ovens. These ovens feature a hydraulic thermostat that is simple, rugged and extremely accurate. It is totally enclosed and the contact points require absolutely no attention. The heating element is designed with a high voltage safety factor and with ribbon elements that resist corrosion and oxidation.

Both the thermostat and the heater element are covered by a five year written guarantee.

Your local Harshaw Scientific representative will be glad to help you select the oven that will best fit your lab requirements.

Immediately Available!

Catalog No.*	Mod.	Max. Temp. °C	Watts	Cabinet wide deep high	Overall wide deep high	Price Iron Ext.	Price SS Ext.
H-52800	100	180	600	13 x 14 x 13	25 x 22 x 28	$195	$235
H-52800	104	260	1200			220	260
H-52800	120	180	1200	25 x 19 x 19	37 x 27 x 34	348	420
H-52800	124	260	2400				460
H-52900	601	180	1400	13 x 14 x 13	39 x 22 x 26	485	
H-52900	605	260	2600				600
H-52900	621	180	2700	19 x 19 x 19	49 x 26 x 33		690
H-52900	641	180	4100	37 x 19 x 25	72 x 27 x 39	880	
H-52900	645	260	5300			965	
H-52910	821	180	2700	19 x 14 x 19	30 x 22 x 61	590	680
H-52910	825	260	3900			655	
H-52970	500	180	800	13 x 14 x 13	25 x 22 x 28	365	405

* Add A to Cat. No. for iron exterior; B for stainless steel.

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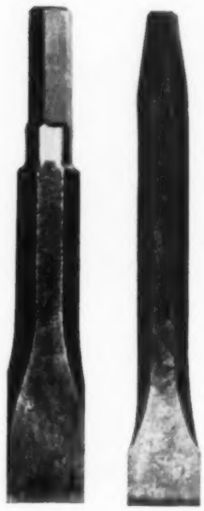
Philadelphia 48, Pa.....Jackson & Swanson Sts.

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

Which chisel has the better design?



Both these chisels, used in pneumatic chipping hammers, are made from shock-resisting tool steel (Bethlehem Omega). One of them consistently gives long service life, while the other is subject to breakage—due directly to its design.

Can you pick out the better design? Look at them carefully. It's the one on the right with the tapered shank.

You still see a lot of chisels designed like the one at the left, that's so susceptible to breakage. Even with the fillet between the round and octagon sections, this chisel is subject to fatigue-failures at the change of section. Stresses become concentrated there, causing premature fractures.

Shank failures are virtually unknown in chisels of the improved, tapered-shank design. The gradual taper prevents any dangerous concentration of stresses.

The comparison of these two chisels helps to explain why it takes more than just good tool steel to get the best performance out of tools and dies. It takes good tool design . . . correct heat-treatment . . . the right grinding technique . . . and proper application. But of course it takes the right grade of good tool steel, too!

Omega halts coupling breakage

Omega tool steel plays a vital role in the drilling of blast holes at the Scrub Oaks and Oxford Mines in the historic iron ore belt of Northern New Jersey. In drilling holes from 35 to 125 ft deep, rods of 1-in. hollow drill steel are joined by patented couplings developed by Ralph Catanzarita, drill-steel-shop foreman at Scrub Oaks mine.

When this method of drilling long holes was first tried, the frequent breakage of couplings was discouraging. Our salesman learned of the trouble and sold them on Omega. This shock-resisting grade did the trick. Coupling failures were reduced to about 1 in 500; and there hasn't been one case of stripped threads.

Omega is outstanding for chisels, and it does a swell job on other cold-shock tools: knockout pins, pawls, punches, swaging dies, clutch pins, shear blades, drive shafts, and machine parts subject to slam-bang shocks. Omega is a tool steel engineered to take the heaviest shocks in its stride. Its typical analysis:

C	Mn	Si	Mo	Va
.60	.70	1.85	.50	.25

It takes a really tough tool steel to take the shock and stress involved in coupling together rods of rock drill steel. The coupling at left is unused. The one at the right has been used in drilling 1700 ft of blast hole in hard iron ore. The outside wearing surfaces have been worn down by the abrasive rock.

TOOLMAKER AT WORK—As this progressive die nears completion, the toolmaker checks dimensions carefully. The die is used to blank, punch and form lawnmower parts from 3/16-in. steel strip. It is made from Lehigh H, a high-carbon, high-chromium grade, and hardened to Rockwell C 60. When placed in service the die turned out about 30,000 pieces between grinds, operating in a 200-ton press.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

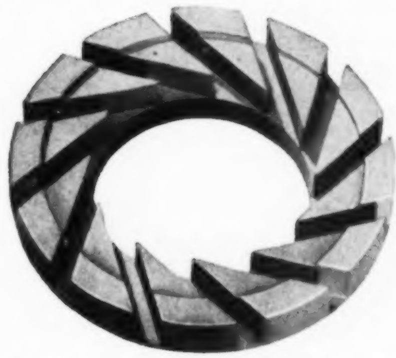
Air-hardening steels should be quenched uniformly

What are the advantages of uniform quenching? First, a minimum of dimensional change or distortion; and second, a minimum of undesirable residual quenching stresses.

Here are some helpful points to remember when quenching air-hardening steels:

- Place the tool on a coarse-mesh screen to permit circulation of air on all sides of the tool.
- Turn over the tool at intervals to improve cooling-uniformity.
- Use a fan or a blast of dry air over the sections which cool most slowly. (Caution: *Too much* air will cause additional non-uniformity.)
- Sections of the tool which cool too rapidly can be wrapped in wire mesh to retard cooling.
- If one portion of the tool turns black long before other portions, you can be sure that it's not cooling uniformly.

This HAYNES STELLITE alloy part *lasted 12 times as long as* this alloy steel part



AFTER
1 YEAR'S
SERVICE

AFTER
30 DAYS'
SERVICE

Micronizer nozzle disks, machined from alloy steel, wore out in just 30 days when used for converting gas house tar into an ignited vapor in a steam generator unit. The abrasive particles in the fuel and the high velocity (39,000 ft. per min.) of the steam rapidly eroded the alloy steel parts to destruction. This same limited service was obtained from disks used in precipitating dust from the exhaust uptake of air-swept coal pulverizers in a power plant.

After considerable testing, investment-cast parts of HAYNES STELLITE alloy No. 19 were adopted as standard equipment. This hard cobalt-base alloy stands up for at least a year under the severe abrasion—outwears the alloy steel 12 to 1. The parts are produced so accurately by the investment casting process that finishing operations are cut to a minimum.

HAYNES precision casting is an ideal manufacturing method for parts that must be made from an alloy difficult to fabricate into intricate shapes by ordinary methods. For more information, write for the booklet, "Investment Castings."

HAYNES *alloys*
TRADE-MARK

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A Division of
Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
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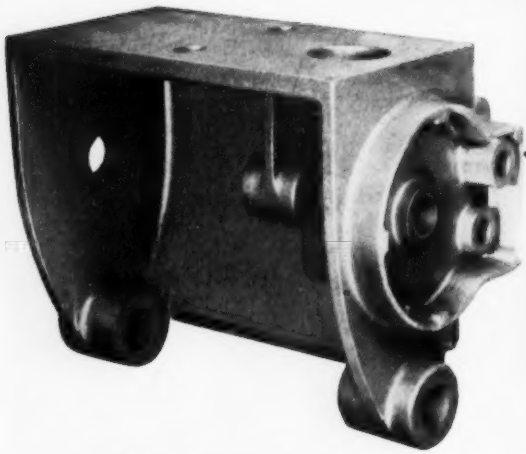
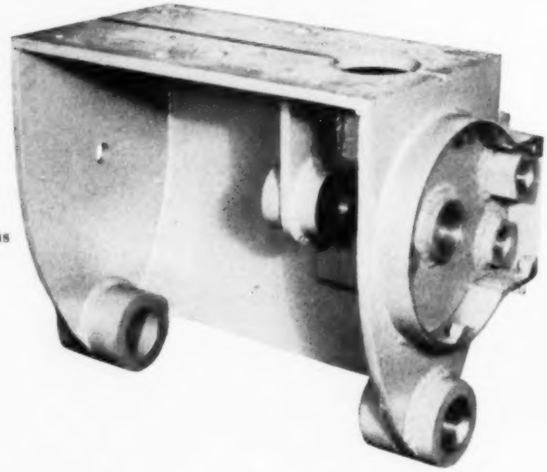
Los Angeles — New York — San Francisco — Tulsa



45% SAVED...
on original cost of part

41% SAVED...
on machine and labor expense

Gearbox for power-driven saw, as cast in Gray Iron.



Fabricated gearbox, which was replaced by the cast design.

By redesigning in Gray Iron, it is often possible to effect substantial cost savings. Here is a striking example:

> The manufacturer of a large power-driven metal saw found that the cost of a fabricated gearbox (right above) was out of line from a competitive standpoint. Designs for a suitable Gray Iron casting were requested and approved. Result:—the Gray Iron casting is effecting a saving of 45% on original cost of the part, plus a saving of 41% on machine and labor expense.

Doesn't this suggest that it's time to analyze *your* costs on certain fabricated parts—with a view to producing them better and more economically in Gray Iron? Write for technical information on the many advantages of the Gray Iron casting process.

GRAY IRON
Characteristics Include:

- Castability
- Rigidity
- Low Notch Sensitivity
- Wear Resistance
- Heat Resistance
- Corrosion Resistance
- Durability
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The hard, cold facts about Pittsburgh's hot furnaces!

47 PLANTS OKAY THE HEAT PROVER

Pittsburgh's great steel industry needed an instrument to measure air infiltration, to check air requirement and fuel-air ratio controls in open-hearth furnaces . . . an instrument to check the stoves in which blast-furnace air is heated . . . to check precise atmospheres in soaking pits . . . to control fuel waste and precise atmospheres in processing furnaces.

THE CITIES SERVICE HEAT PROVER WAS THE ANSWER . . . and it received the stamp of approval from engineers in 47 different mills in and around Pittsburgh!

Cities Service Heat Provers . . . *not an instrument you buy, but a service we supply* . . . helped to boost furnace productivity through these five unique advantages:

1. Rapid continuous sampling.

2. Simultaneous reading of oxygen and combustibles.

3. Direct measurement of oxygen and combustibles.

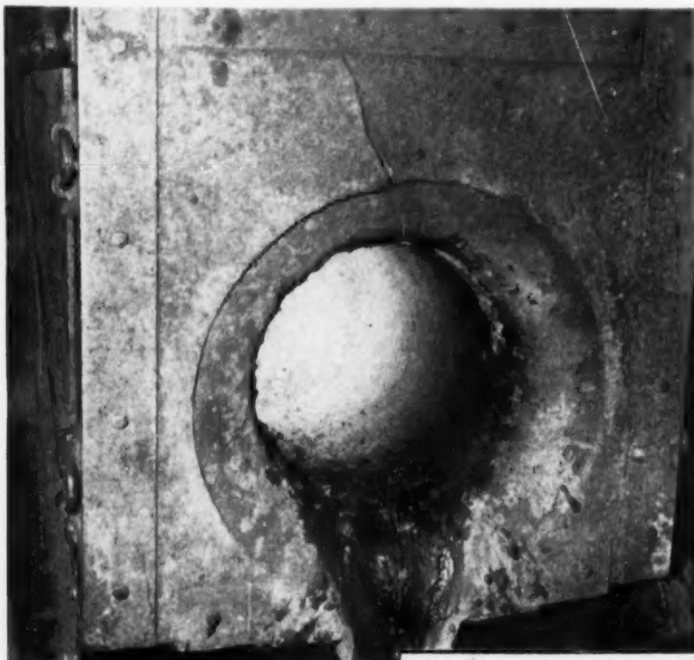
4. Easy portability.

5. No maintenance; no re-calibration.

These points begin to tell you why Cities Service Heat Prover analyses are just as much favored in glass, ceramics, steam generation and other fields as in the great Pittsburgh steel area. For the full story as it applies to you, write CITIES SERVICE OIL COMPANY, Dept. A20, Sixty Wall Tower, New York City 5.

CITIES SERVICE

HIGH ALLOY STEEL is being poured here from a 1000-lb. high-frequency induction furnace. It is lined with a Norton MAGNORITE* refractory cement which lasts 16% longer than the cement previously used.



CLOSE-UP OF THE SAME FURNACE, taken immediately after metal has been poured, shows how effectively this engineered-to-the-job Norton MAGNORITE cement resists mechanical and chemical attack.

How much more steel will you melt per lining *with Norton MAGNORITE cements?*

It's easy to find out how much longer Norton MAGNORITE refractory cement will last in your high-frequency furnaces than your present linings. Just call on the 40-year problem-solving experience of Norton Refractory Research which gave this satisfied customer (name on request) 16% longer lasting linings.

Whether you melt straight steel or heat-resistant compositions, you'll get a Norton MAGNORITE cement that's engineered to fit your exact requirements. It will withstand temperatures up to 3250 F. if need be. It will have a high-rammed density that offers great resistance to metal penetration, erosion and chemical attack . . . and freedom from shrinkage cracks that often lead to furnace failure. Why not run a test on one of your furnaces soon?

Whatever your metal-melting problem, you can depend on Norton Research to help you. Working with MAGNORITE, ALUNDUM*, CRYSTOLON* and FUSED STABILIZED ZIRCONIA cements and special shapes, Norton engineers are sure to come up with the right answer for you.

For full details about Norton special, engineered refractories, contact your nearby NORTON refractories engineer, or write to NORTON COMPANY, 32 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

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Making better products to make other products better

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Metal Progress . . . . . . January 1953 Vol. 63, No. 1

The front cover for this issue is the work of Miss Marianne Reihard, herself a displaced person starting a new life in America. The design was drawn on a smooth sheet of aluminum foil with stylus, and the result photographed under strong oblique light.

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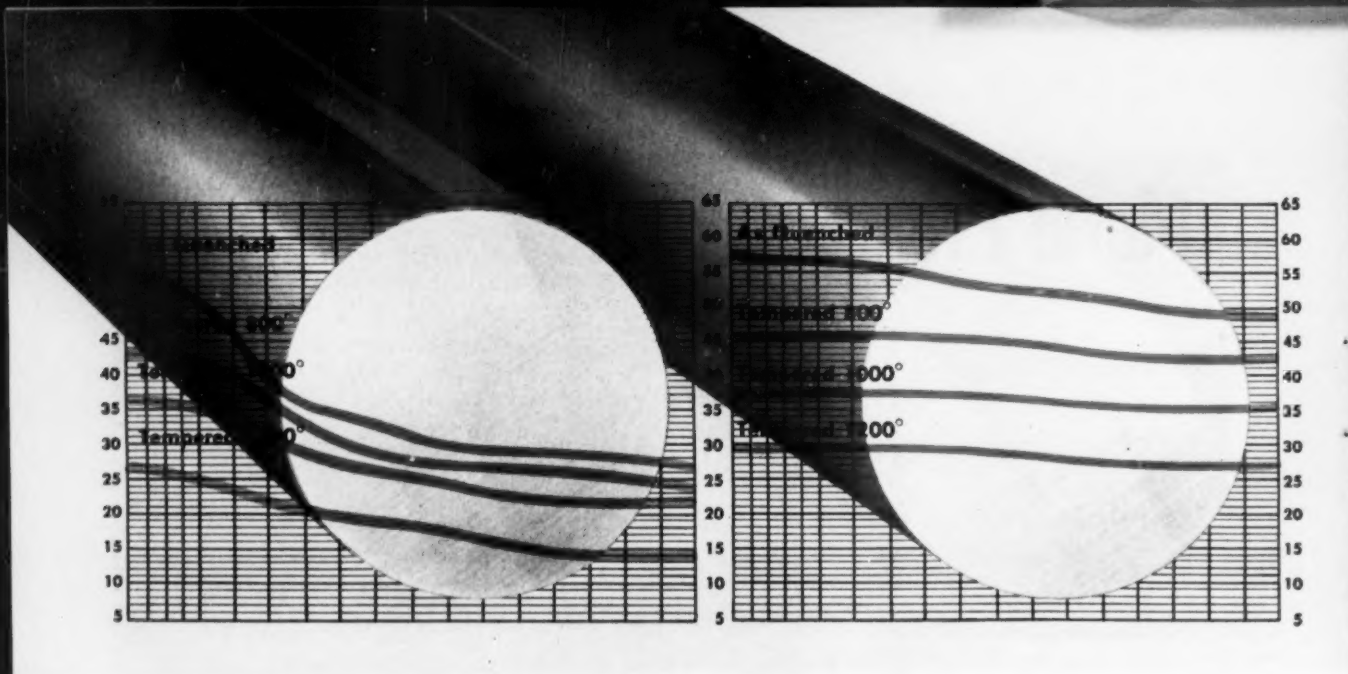
Correspondence

Digests of Important Articles

Departments



Same Alloy...but *What a Difference!*

Graphic Reason for Using Ryerson Certified Alloy Steel

Here are two bars of alloy steel recently purchased by a metalworking company. Both are the same type of alloy—AISI TS 4140 annealed. And both are high quality steels with chemistry meeting all the requirements of the specification.

But look at the difference revealed by hardenability tests!

The tempered-at-800° curves are typical. For the bar at left this curve starts at 44 Rockwell C and ends at 24. For the bar at right the same curve starts at 45—ends at 42. And the differences in hardenability naturally reflect equally marked differences in the mechanical properties that can be obtained from each bar.

Yet remember both bars are the same alloy and therefore are often expected to react in the same way. Their differences are only the normal variations that occur between different heats within the same specification.

That's why it is so important for you to specify and buy Ryerson Certified Alloys. *Every heat* of as-rolled and annealed alloy steel from Ryerson has been tested for hardenability in our own laboratory. When you receive a shipment of Ryerson alloys you also receive a Ryerson Alloy Certificate which shows exactly how *your particular heat of steel* responded to those tests. And the Certificate interprets the test results for you in terms of mechanical properties.

Thus you know the actual—not just the theoretical—hardenability of your alloy steel from Ryerson. And you know exactly how to heat treat that steel to obtain the desired properties. So why guess at hardenability? Use Certified Ryerson Alloys and be sure.

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RYERSON STEEL

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Metal Progress . . . . . . January 1953 Vol. 63, No. 1

To Begin With —

– this first issue of *Metal Progress* in the new year 1953 is possibly worthy of comment in two respects.

Primarily, in its textual pages it begins what we anticipate will be a series of annual reviews of metallurgical progress throughout the civilized world. The idea that this should be done stemmed naturally from the First World Metallurgical Congress, held under the auspices of the American Society for Metals in Detroit 15 months ago. During that Congress a luncheon was given the chairmen and secretaries of the eleven study groups from abroad by the ASM Board of Trustees, wherein Secretary Eisenman voiced the hope that the newly made contacts between overseas conferees and their American counterparts would blossom into something more substantial than an interchange of Christmas cards. The collection of a budget of information from sources far and near in each New Year's issue of *Metal Progress* is one way wherein the objective of cementing the professional interests of metals engineers everywhere can be achieved.

Despite the fact that this magazine contains nearly double the reading pages usually printed by *Metal Progress*, it has been necessary to postpone three of the special articles – one from Canada and two from the United States. The geographical coverage also leaves something to be desired. While the editorial staff is by no means ashamed of this first attempt, we know there remains plenty of room for improvement – and that is something fine to look forward to and to work for.

Each article is by an undoubted expert. Each author was asked to write about postwar developments in his field of competence. This avoids overlap and avoids that pit into which most "annual reviews" eventually fall – a repetitious abstract of published literature. It also results in a series of articles among which, we believe, every ASMember can find one which applies to his special interest.

The second aspect which our readers will notice is our new typographical dress.

Before *Metal Progress* was established, in September 1930, advice was sought from one of New York's leading typographers. He suggested oversized pages of generous margins, large illustrations, uniform hand-drawn diagrams, and a then-new type face known as No. 16 Linotype. The large paper size was a victim of wartime paper shortage, but since the depths of the depression, money has always been found for attractive front covers. (Since three quarters of the magazines are mailed to the home rather than the office of the reader, they must compete in looks with glamorous covers on magazines selected by the wife.)

All in all, *Metal Progress* set a high mark in mechanical excellence, as is attested by five awards in national competition, and under such circumstances any proposal for change was looked upon with skepticism. However, it should be obvious that, in these years of rapid change, anything which still wears the dress of a past generation gets to look somewhat old-fashioned.

For some months, therefore, *Metal Progress's* art director, Floyd E. Craig, has been working with Helm Spink, Cleveland typographer, on this problem of modernization. Of several layouts the one now appearing was adopted. Color appears on the text pages for the first time. To those interested in technical details, the text is set in "Caledonia" (one of Linotype company's newest type faces) and the heads are set in "Dom Casual".

We hope you like it.

Ernest E. Thum
Editor, *Metal Progress*

ALFRED J. MURPHY

A professor of industrial metallurgy at the University of Birmingham since 1950, he is also chairman of the Inter Service Metallurgical Research Council which advises the British Government on metallurgical research and development. His scientific publications on such subjects as aluminum and magnesium alloys, aluminum bronzes, cracking of boiler plates, and iron chains have been read before many technical societies, including the Royal Society, Royal Microscopical Society, and Institute of Metals. Professor Murphy was president of the Institute of Metals in 1951-52; and has served in various official capacities for the Institution of Metallurgists, British Nonferrous Metals Research Assoc., and Institute of British Foundrymen. He is a graduate of the University of Manchester with a First Class Honours degree in chemistry. From 1927-31 he was on the staff of Dr. W. Rosenhain at the National Physical Laboratory, then went into industry as chief metallurgist and later a director of J. Stone & Co., Ltd., London. Under his direction the first studies in Britain were made of the magnesium-cerium alloys establishing their excellent creep resisting properties, which have led to their extensive use in gas turbines for aircraft. During this period he was on the boards of directors of Stone-Fry Magnesium Ltd. and Light Metal Forgings, Ltd.

The Free World's Metal Resources and Expected Demand

METAL ECONOMICS is a convenient term for the field of study in which the topic of this review lies. By this we mean to convey not so much a branch of the formalized science of economics as a consideration of those principles extending beyond strictly technical metallurgy which affect the availability of metals and which influence the efficiency of commercial utilization. To those of us who have become increasingly concerned with the impact of metal economics on industrial metallurgy, it is heartening and significant to find the subject given a place in this World Review of Metals Engineering by *Metal Progress*. A notable stimulus to interest in the same direction was provided by the reports of the conference on conservation and utilization of resources organized by the United Nations' Economic and Social Council at Lake Success in 1949. For authoritative data and an informed analysis of the materials problem, especially as it affects the United States, investigators in this field will make frequent reference to the monumental reports of the Paley Commission (The President's Materials Policy Commission). Of the five volumes published in June 1952 the second, entitled "The Outlook for Key Commodities", is of special value, since it embodies the conclusions of groups of specialists on the trends of demands, estimates of reserves and scope for economies in reference to the principal metals of industry. In a modest way the British Institute of Metals has provided a forum for discussions of metal economics, devoting a general meeting to the topic in October 1951.

This is the first generation of engineers and technologists which in peacetime has had to cater for a real failure of supplies of metals to satisfy demands. The title of this brief survey refers to the expected demand in the future; the scope and the manner of treatment of the subject depend unavoidably on how far ahead we are looking. If "the future" were understood to refer only to the short term of the next

three or five years, our concern would be mainly to establish the facts of inventories, and current rates of production and consumption; extending the meaning to embrace a term of 15 to 20 years allows recognizable long-range influences to be taken into account and strengthens the technical interest of the argument. The scale of operations and the magnitude of financial investment in modern metal-winning industry make necessary periods of amortization rarely less than ten years and estimates of mineral reserves look at least as far ahead. It is evident, therefore, that we should be closing our eyes to factors of immediate significance if we excluded from consideration measures aimed at developments of longer term. On the other hand, in order to enjoy the fruits of long-term planning we must first survive the short-term difficulties!

THE SHORT-TERM POSITION

In the postwar years we have encountered shortages of steel, copper, zinc, tin, lead and nickel sufficiently serious to cause restricted production in engineering undertakings or to compel substitution by other materials. During this period there have been anxious debates as to the future relations which these current shortages portend. See, for example, John Mitchell's thorough discussion of conservation of scarce metals in American constructional alloy steels in *Metal Progress* for October 1952. In some cases supplies of nonferrous metals have improved within the last year to an extent which has permitted the relaxation or abandonment of control on end-use. Thus, in Britain the total prohibition of the use of zinc for galvanizing steel and ironware articles other than water containers and pipes, which was in force for about 18 months, has been canceled. To some these reliefs demonstrate the fallibility of planners and indicate a lack of foundation for the gloomy prognostications of continuing shortages; to others they represent only the minor ripples in a curve relating supply and demand which they believe is moving in its main course toward a chronic state of metal insufficiency.

To correct *quickly* a shortage in supply, the opening up of new mines or the installation of new plant for the treatment of minerals cannot be effective because of the time required to bring them to production. It is necessary, therefore, to see what can be done to make available without delay and in acceptable form the metal which has already been won and more or less widely dispersed. This metal exists as stocks in warehouses, as material in process of fabrication, as finished articles and as available scrap.

IRON AND STEEL

In respect of possible windfalls from any of these sources the position of the ferrous metals is different from that of the nonferrous. The rate of consumption of steel is so enormous that it is not safe to reckon on the existence of any strategic *stockpile* on which to draw in an emergency; at the other end of the scale, *scrap* has for so long constituted one half of the weight of the raw material of the steel industry and there have been so many intensive drives for the recovery of steel scrap that there is little prospect of any dramatic early alleviation of the world shortage of steel. Satisfaction of demand can come only as quickly as new blast furnaces can be built and brought into operation to provide the pig iron which must replace the missing scrap.

It is useful to recall the relative proportions of the raw materials consumed by the iron and steel industry. Nine tenths of the world's steel is made in openhearth furnaces and the situation is, therefore, dominated by the requirements of this melting unit. To produce 100 tons of steel ingots from the openhearth, 110 tons of metal is charged and of this about one half is pig iron from the blast furnace, and the remaining 55 tons is scrap. The 55 tons of scrap is made up typically of 30 tons of "home scrap" – that is, scrap originating in the foundries and mills of the steelworks, and 25 tons of "bought-in" scrap. The latter, in turn, comprises nine tons of "prompt industrial scrap" – borings, clippings and punchings from the makers of finished steel goods – and 16 tons of "old scrap" – that is, steel and iron articles discarded because of wear, damage or obsolescence. This latter item, the old scrap or reclamation scrap, is the object of the salvage drives; experience generally shows that the yield is disappointing in relation to the zeal and effort expended. The other grades of scrap are automatically generated during the operations of manufacture and they become available for re-use within about three months. Contrariwise, the cycle of reappearance of old scrap is much longer and, in fact, the records show that the supply of this commodity in any one year is roughly equal to one third of the output of finished steel

products 20 years earlier. The shadow of the depression years of the early 'thirties, with their abnormally low production of steel goods, falls now on the steelmakers two decades later, who see it as a deficiency of obsolescent scrap.

To the extent that new pig iron has to take the place of scrap there is a simultaneous need for more iron ore, coke and limestone, since to produce each extra ton of pig iron there are consumed about 1¾ tons of iron ore, 1 ton of coke and ½ ton of limestone. The repercussions of a shortage of scrap are evidently numerous and extensive and it can be understood that they constitute formidable barriers to a speedy solution of the problem presented by a shortage of scrap.

NONFERROUS METALS

The short-term position of the nonferrous metals for the most part lacks the element of orderliness discernible in the steel situation; indeed the rapid changes between shortage and plenty of copper, zinc, lead and tin during the last three years are quite capricious.

The summarized world figures for production and consumption of the metals copper, zinc, lead, aluminum and tin for 1948, 1949 and 1950 are given in Table I, together with the additional purchases (shown in the fifth column) for "U. S. Special Account". This item is generally taken to represent the purchases for stockpiling. From this résumé it is seen that, excluding stockpiling, during 1948-1950 production of these five metals was more than sufficient to meet consumption, but that the operations of stockpiling converted a surplus into a net deficit in copper, zinc and tin. The effect for copper was particularly severe. The stockpiling absorbed 5% of the world's production of copper and zinc, 8% of the lead and 21% of the tin, and this was held to be the cause of the shortages of copper, zinc and tin in September 1951. The year 1951 (which has been described as the most difficult postwar year for consumers of metal, in terms of both cost and supply) brought rearmament to cancel any relief from stockpiling, but saw two alleviating changes – namely, the establishment of the International Materials Conference (I.M.C.) with its scheme of allocations, and the beginning of production from new mining undertakings. These influences, with the deliberate spread-out of Western rearmament programs, have progressively eased the short-term position to the extent that zinc has been removed from the list of materials subject to international allocation, and I.M.C. has been able to make substantial increases in the latter half of 1952 in the available tonnages of copper, nickel, tungsten, molybdenum and cobalt. Lead and tin have not been brought into the scheme of allocation.

The less tense atmosphere is reflected in the British economy by the change as shown in Table II in the figures for consumption of copper, lead and zinc from the last half of 1951 to the first half of 1952, and in the stock position at the end of the respective periods.

Even though these figures, baldly presented, probably give an unduly rosy tinge to the picture by their indication of supplies permitting a clear increase in the net total of consumption plus stocks, the *Board of Trade Journal* mentions only three important nonferrous metals – copper, aluminum and nickel – of which the consumption would have been higher in the last six months if more supplies had been available. This position could be changed profoundly either by a sudden increase in the tonnage of steel available for use (because many uses of nonferrous metals in manufactured products depend on the release of steel) or by changes in the American economy. It is to be noted that the greater portion, perhaps two thirds, of the acquisition of metal for the U. S. stockpile is still to come.

So long as there is actually less metal available than the total for which there are would-be buyers, it is difficult to gage the magnitude of the shortfall. It would appear that in lead and zinc

Table I – World Production and Consumption for Three-Year Period, 1948, 1949, 1950*

(In thousands of metric tons; 1 metric ton = 1.102 short tons of 2000 lb.)

Metal	Total Production	Total Consumption	Excess or Deficit	Purchases for U. S. Special Account	Total Excess or Deficit
Copper	7,065	6,940	+125	384	−259
Zinc	5,063	4,868	+195	273	− 78
Lead	4,549	4,072	+477	354	+123
Aluminum	3,529	3,447	+ 82	31	+ 51
Tin	507	402	+105	107	− 2

*Taken from "Metal Economics", *Journal* of the Institute of Metals, Vol. 80, 1951-52, p. 227.

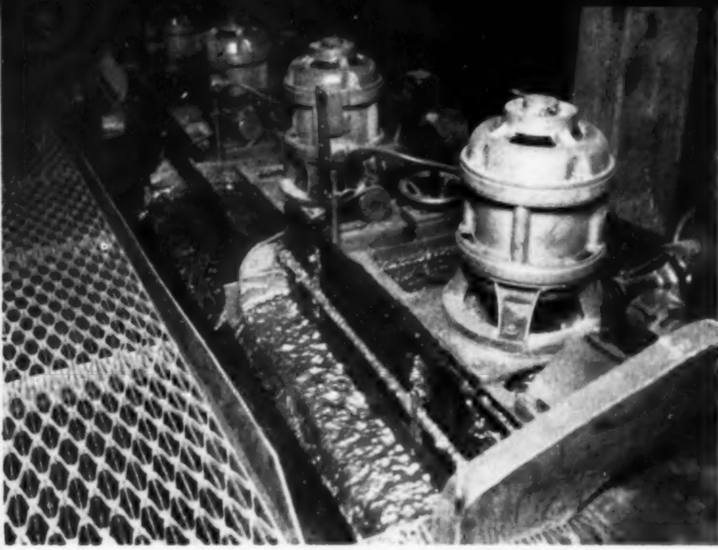

Fig. 1 – Flotation Cell at the Utah Copper Division of Kennecott Copper Corp., Magna, Utah

Precarious Optimism Voiced

the discrepancy in the postwar years between supply and real demand was not very great. The combined effect of government restrictions on uses and of price increases stimulated trials of substitutes; on the other hand, they brought out old scrap by the attraction of profitable disposal.

The automobile accounts for more than 40% of the lead consumed; in the U. S., storage batteries take 34% and tetra-ethyl lead in gasoline 10% of the total. The return of the battery lead as scrap is prompt and the yield high – about 85% – but the lead added to gasoline is wholly dispersed and lost. Neither of these important uses is likely to have abated recently or to be replaced in the near future. Cable covering absorbs 11% of the lead; substitution by plastic and aluminum has already eased the pressure on supplies of lead for this application.

Apart from temporary legal prohibitions, the sharp rise in the price of zinc and the lack of indications of an early fall have strongly encouraged substitution. Until 1945 zinc had always been the cheapest nonferrous metal per unit of volume; this, together with its admirable suitability for pressure die casting, gave it an unchallenged supremacy in this field. (In the U. S., die casting absorbed 20% of the zinc used in 1950.) In the last few years, however, the price of aluminum has fallen to a level which makes the cost per cubic foot less than half that of zinc. Magnesium with its still lower figure for density can show similar economic advantage, even at a higher price per ton. As a consequence, the light metals are increasingly taking the place of zinc for pressure die castings.

It appears then that, in the short term, we have survived. In seven years the world's metal-winning and metal-using industries have had to change gear from a war economy to a peace economy with greatly changed gradients of demand, then to make a second emergency shift to the economy of a cold war, a terrain in which we had no experience for guidance. It is hard to believe that the near future can be preparing more acute problems in this particular sphere of human trials and tribulations than we have yet encountered.

With this precarious optimism as to the short term, let us consider the likely trend of events over a longer period.

THE LONG-TERM POSITION

Statistics available for the last 50 years – and in some items going back for a whole century – are sufficiently numerous and reliable to justify reasonably confident extrapolations of the course of world population and of the demand for primary metals over the next 20 years. Since the beginning of this century the average rate of increase of the world population has been close to 1% per annum. The index of world food production has moved at almost exactly the same rate. For instance, taking the values in 1913 as 100:

Year	Population	Food
1929	113	116
1937	124	125
1950	138	131

Over the same period from 1913 to 1950 the total tonnage of world production of the principal industrial nonferrous metals more than doubled. It appears that while man's consump-

Table II – United Kingdom Consumption and Stocks
(In thousands of long tons; 1 long ton = 1.12 short tons of 2000 lb.)

Metal	Consumption			Stock		
	July to Dec. 1951	Jan. to June 1952	Change	Dec. 31, 1951	June 30, 1952	Change
Copper	162.3	187.7	+16%	119.3	111.7	−6%
Lead	73.3	46.8	−36	74.0	121.6	+64
Zinc	97.3	93.4	− 4	37.5	87.5	+133

Metals an Index to Standard of Living

tion of food per head has remained unchanged, his appetite for metals has grown enormously. We may safely take the demand for metals as an index of the standard of living. These statistics, therefore, show that we are faced with an increasing population claiming an enhanced standard of living.

In trying to picture the demands on resources toward which these two processes are leading, it is necessary to bear in mind how much leeway would have to be made up by the rest of the world before its average even approached the present standards in the United States. A graphic illustration, which has been quoted before, of the consequences of advances in standard of living is that if the employment of copper per head in the rest of the world rose to be half of that in the United States the world production of the metal would have to be increased from the present figure of 2,400,000 to 10,900,000 tons per annum!

We are therefore contemplating inroads at an accelerating rate into a store of mineral resources in the earth's crust and the oceans; we know that there is no replenishment of the store as there is in vegetable resources, and the logical end of the story of metals is evidently the complete exhaustion of supplies. Enough is known, however, about untapped reserves and the potentialities of new discoveries and about rates of consumption to justify the belief that such a *dénouement* is a contingency so remote in time – with one or two exceptions – that it need hardly cause us more acute concern than does the prospect of the polar ice caps extending once again to cover the middle latitudes of the globe.

On the whole, the economists are more gloomy than the producers of metals. Accepting the predictions of an upward swing in demand under the pressure of increasing population, the producer reflects on the success with which he has met similar calls in the past. He sees that not more than two thirds of the land surface of the earth has been explored for metals – some of that rather cursorily – and guesses that there must be large unknown resources still awaiting location. New methods of geophysical prospecting and the use of aircraft greatly facilitate and expedite surveys. In the already known mining regions annual yields may be multiplied by new discoveries and by advances in technology enabling poor ores and those in difficult sites to be worked profitably. The producer has considerable faith in the efficacy of the price mechanism to stimulate production. It may be significant that "primary" goods as a whole are increasing in price in relation to "secondary" manufactured goods; these are the conditions which make prospecting profitable and attract capital for investment in mining ventures. The question is whether the primary producer takes sufficient account of the effect of advancing standards of living on the consumption of metal.

In the main, the economists foresee the future demand for metals rising at a greater rate than the supply. It may be that they place too conservative an interpretation on the reports of mineral resources. It must be said in this connection that the curves of world production since 1913 for all the major industrial metals

Fig. 2 – Texas Plant of Dow Chemical Co., Showing Sea-Water Intake Gate in Center. It is estimated that a cubic mile of sea water contains 12 billion lb. of magnesium. All of the magnesium produced to date from this source has used less than one tenth of a cubic mile, and there are some 320 million cubic miles of sea water available

except lead and aluminum have risen in much the same proportion as the Index of Industrial Production. For lead, production has not merely failed to rise at this parallel rate; it has, in fact, fallen from about 1,700,000 metric tons in 1927 to 1,500,000 in 1950, a period in which the Index of Industrial Production has doubled. Aluminum presents an opposite picture, having trebled its production in that span of time.

The records of actual production and of industrial activity over the past 25 years do not, therefore, in themselves provide grounds for anticipating an over-all shortage of the important high-tonnage metals in the calculable future; neither do they give assurance that the balance so far achieved will be maintained. The fact is that the acceleration of demand proceeding from the world-wide urge toward improved standards of living is a factor of great potential importance, the future strength of which cannot be predicted solely from past records. It is fairly safe to assume that for some time the percentage increase from this cause will be higher in the countries outside the United States than in the U. S. itself, since the latter is already so much further advanced. The Paley Commission has made an attempt to assess the relative magnitudes of the future demands from the United States and from the rest of the non-Communist world. The situation as it is now and as the Commission foresees it in 1975 – admittedly a long extrapolation – is summarized in Table III, in which figures of population are partly taken from other sources. The Industrial Free Countries are Europe, without Russia and Russian satellites, United Kingdom, Canada, Australia, New Zealand and Japan. It is to be noted that the combined population of the U. S. and this group, 564 million, is only about one quarter of the total population of the world, estimated in 1949 at 2,377 million, but the groups named in the table comprise the major consumers of metals.

Paley Forecast to 1975

Within the period of the next 25 years the Paley Commission evidently sees the demand accelerating in the other industrial free nations at a greater rate than in the United States, but even so the consumption of metals per capita in the other countries will remain only a fraction of that in America.

The anticipated demands for steel, copper, zinc and lead do not look unreasonable in relation to the projected increase of 100% in the gross national output in the U. S. from 1950 to 1975. The expected increase by three and four times in the consumption of aluminum in the U. S. and the rest of the free world in the same period is the most striking feature of the table.

RESOURCES

What are the resources from which these demands are to be met?

First we must consider the mineral reserves in the ground. This is a matter on which serious misapprehension has existed in some quarters. There are three categories of reserves:

A. "Known" or "proven" or "measured" ore, the quantity of which has been computed from closely spaced drillings.

B. "Indicated" ore, which has been computed from samples and data from sites more widely spaced than in (A) with a corresponding decrease in precision.

C. "Inferred" ore, estimated on broad knowledge of the geological character of a deposit.

The geologist and mining engineer are prone to write of "known" or "measured" reserves without emphasizing the adjective, and although this is safe in mining circles, it may cause misunderstanding when read by others not so intimately acquainted with the industry. The tonnage of such *proven* reserves, if divided

(Continued on p. 172)

Table III – Projected Demands, 1950 to 1975, in Thousands of Short Tons

Year	Population	Crude Steel	New Copper	New Zinc	New Lead	New Aluminum
		Estimates for the United States				
1950	151,000,000	96,800	1,255	1,081	784	920
1975	193,000,000	150,000	1,800	1,500	1,200	3,600
Increase	28%	55%	43%	39%	53%	291%
	Industrial Free Countries (Free Europe, U. K., Canada, Australia, Japan)					
1950	413,000,000	62,100	1,188	972	743	465*
1975	486,000,000	104,300	1,720	1,588	1,177	2,400*
Increase	18%	67.6%	45%	63%	58%	415%*

*Entire free world outside U. S. A.

Fig. 1 – A Modern 70-Ton Electric Furnace at the Los Angeles Plant of Bethlehem Steel Co., Where Electrics Have Entirely Replaced the Openhearths

Progress in

FEELINGS about current progress – or forward motion – in steelmaking processes depend upon point of view. Chemical engineers filled with pride of accomplishment in, say, petroleum technology have been known to cite the steel industry as the ultimate model of backwardness in these enlightened times. This sort of thing could be confusing to Mr. Average Citizen, who, having gained considerable respect for the achievements of chemistry and physics since Dec. 8, 1941, now reads in the papers about how steel capacity of this country has well passed 100 million ingot tons and that 120 million is the next target number. His confusion could be still greater if he happens to realize that by far the greater fraction of useful product of this enormous tonnage sells for a few cents a pound.

Delivery of the goods in such fashion suggests that critical friends in the chemical industry have overlooked something. As a matter of fact, experience shows that the non steelmaker is inclined to overlook several somethings. First, there is that item of a few cents per pound; only the village idiot can hold out for a new and beautiful process if it costs more to operate than existing processes. Despite this, many a steelmaker, for refusing to be stampeded by a "why don't you do thus and so", is accused at very least of being hopelessly Tory. A further item overlooked by facile critics is that the suitability of even a given existing process is ordinarily determined by factors other than simple technology of steelmaking.

Even though pursuit of these matters may be vastly entertaining, such must occupy a subsidiary position in this discussion, limited to steelmaking processes.

FUNDAMENTAL CONSIDERATIONS

The fundamental operations of steelmaking are so simple in principle, yet the steel plants are so vast that it is safest to review the principles briefly. Reduced to minimum words, steelmaking consists of acquiring a container of liquid made up mostly of the element iron, then adjusting its composition to some predetermined pattern. The first operation, "melting", is physical in nature and is not necessarily conducted in the steelmaking unit. The second operation, "refining", is chemical in nature; it consists mostly of removing unwanted substances by various expedients to the extent required in the finished product.

The reason for repeating the simple fact that melting is physical in nature and that refining is chemical in nature is that herein lies a useful starting point for thinking about how fast steel can be made. For the melting operation, a bit

of reflection produces the conclusion that rate of melting is a function only of the rate at which heat can be pumped into the charge and that this is virtually without limit; the empiricist can get the idea quickly by connecting a flashlight lamp to a house circuit.

The refining operation, however, is altogether different; it consists of a number of simultaneous chemical reactions for which there is a specific rate fixed by nature for each; nothing can be done about this. Specific rate is used here in the meaning of the physical chemist; it says nothing about how fast a given reaction will proceed in a given process. The reaction of carbon and oxygen in liquid iron – the most important of them all – is a case in point; that which requires hours in an openhearth furnace can be accomplished in minutes in a bessemer converter, yet there is evidence that the carbon-reaction rate in the conventional converter is a fraction of that indicated by the physical chemist's specific rate.

By JOHN S. MARSH
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Steelmaking Processes in America

Although quantitative details are incomplete for the various reactions constituting refining, there is ample evidence that all are inherently much faster than would be suggested by their behavior in conventional steelmaking processes. This at once implies that the difficulty lies in getting reactants together, or in removing resultants, or in both. All refining reactions involve oxygen in one way or another; those for carbon, silicon, manganese, and phosphorus are direct oxidation. Since this is true, it follows that rate of supply of oxygen to the reaction zone is an important factor. (Possibly it is the limiting factor.)

In a closed system, reactants and resultants tend to establish equilibrium conditions. If, however, the reaction product can be removed from participation, the reaction can proceed further. The number-one example of this is, of course, the carbon reaction, for which the product is a gas; the reaction product is removed from the reaction zone by escape to the atmosphere, and the process of carbon removal proceeds. In basic processes of steelmaking, the product of the silicon reaction is removed effectively from participation by strong combination with lime, with the result that removal of silicon from the metal is substantially complete. Other oxidizable substances distribute themselves between slag and metal in a definite way which depends upon composition of metal and slag and upon temperature. And so on.

APPRAISAL OF STANDARD PROCESSES

The only point to the foregoing is that it provides a basis of judgment of existing steelmaking facilities in terms of how good – or bad – they are as reaction kettles. If optimum economy in steelmaking requires that refining is to take the minimum possible time (as may be assumed as a first approximation), mixing of slag and metal must be intimate and oxygen must be supplied at least as fast as it can be consumed. It may be perceived at once that the openhearth and the electric furnace are not good reaction kettles. Both contain relatively deep baths with relatively low ratios of surface to volume; diffusion paths of reactants coming in from the outside are long. In fact, in the openhearth and in the electric furnace operated under oxidizing conditions, refining would be an exceedingly slow process were it not for the stirring action produced by gas bubbles from the carbon reaction. A king-sized version of the kitchen blender, capable of extended service at steelmaking conditions of temperature and corrosion, would be most acceptable. If oxygen supply were the only factor to be considered,

it would be hard to improve upon the bessemer converter as a reaction vessel; the converter, however, is not well adapted to slag manipulation and it has other limitations.

The three processes – openhearth, electric and bessemer – account for substantially all ingot capacity, with the openhearth process far in the lead in the United States. Each exists in acid and basic versions; thus, there are six possibilities. However, the choice is far from arbitrary; each has its advantages and its limitations. If the product is to be steel of phosphorus and sulphur ranges ordinarily specified for wrought grades, the acid processes cannot make large tonnages, because there simply is not enough raw material of suitable purity. This is as true of acid bessemer practice as it is of acid openhearth and acid electric.

Steelmaking in America consumes nearly equal fractions of scrap and pig iron and, as is very well known, by far the greatest fraction of total iron units is consumed by basic openhearths. Many plants operate on a mix not far from the national average; for such a mix, there is no known device better adapted to its task than the basic openhearth. The electric furnace can do a faster job at melting an all-cold charge, but it is incapable of handling large fractions of molten pig iron. The bessemer converter is without equal for rapid decarburization of hot metal, but its scrap-handling ability is limited. An obvious trick is to combine operations (duplexing). Thus, a basic openhearth furnace may be charged with hot pig and metal decarburized and desiliconized in an acid converter, or with scrap and partly blown metal.

All processes in use today, singly or in any combination, are batch in nature which, on general principles, is likely to give our friend the chemical engineer the horrors. The steelmaker must agree that the continuous processes of the chemical industry are so intellectually satisfying that he would be delighted to do some serious planning if the chemical wizards would provide materials of construction capable of withstanding the combined attack of temperatures in the neighborhood of 2900° F. and ever-present iron oxide. Perhaps some substance will be found that is resistant enough, abundant enough, and cheap enough – but the odds are not attractive. The only apparent solution to the immediate problem of supplying additional capacity appears to be through making the most of existing processes and this is precisely what the industry is doing.

In this country, effort is naturally mostly concentrated on the basic openhearth furnace, although electric furnace operators are also very active. Principally in Europe, there is activity in exploring the possibilities of basic bessemer operation, largely but not solely because of their abundance of high-phosphorus ore. The principal disadvantage of a conventional bessemer operation, either acid or basic, as we see it is that it cannot produce steels of low enough nitrogen and phosphorus content for applications requiring high ductility. Bessemer himself pointed the way years ago, so far as nitrogen is concerned, by noting that iron could be blown with oxygen, steam, other oxidizing gases, or mixtures, as well as by air blast.

By using such mixtures, by control of steel temperature and interval operation in basic converters, and by special dephosphorization, steels are now being produced in Europe that would be difficult to distinguish from the openhearth product, and this is an excellent example of the fact that selection of a process is not arbitrary – the choice here, as is often true, is dictated by the raw materials available. However, again because of raw materials, the basic bessemer process is no factor in America and this state of nonexistence is likely to continue.

In some instances it is the product that determines the steelmaking process; for one example, only the electric furnace is suitable for the making of highly alloyed steels. For another, the basic openhearth is likely to be most suitable for the making of "low-everything" sheet steel because of its ability to handle charges predominantly of hot metal, which dilute those residual elements which are often a problem with high-scrap charges. The tendency to use a specific process for a specific product, however, was much stronger a few years ago than it is today; for example, electric furnaces are now making openhearth grades and basic openhearths are making acid bessemer grades. Again, resulphurized screw stock, once an exclusive bessemer product, is now produced in substantial tonnage in basic openhearths.

ECONOMICAL STEELMAKING MEANS FAST MELTING

Such adaptability is commercially advantageous, but is a minor factor in accounting for sharply increased productivity of the last few years. Much of the additional capacity is ascribable to entirely new melting facilities, but another large part has resulted from improved operation of existing facilities.

The outstanding feature of recently improved operation is the now-keen appreciation of steelmakers for the fact that fast steelmaking means fast melting. Electric furnaces are being equipped with bigger and bigger transformers for just this purpose; to an outsider this might seem an obvious thing to do, but the operators know from bitter experience that higher voltages and currents are not to be slapped on carelessly. More spectacular, at least to this observer, are advances in openhearth operation. Not so many years ago, 12-hr. heats at a cost of over 5,000,000 B.t.u. per ton were common. Now there are whole shops averaging 8-hr. heats with heat consumption under 3,000,000. Individual furnaces have operated for a month with an average fuel consumption of a trifle over 2,400,000 B.t.u.; on the basis of theoretical requirement of 1,000,000 B.t.u. as the nearest round number for the conventional scrap plus hot metal charges, this means a thermal efficiency in the neighborhood of 40%. As thermal engines go, this is not at all bad and is vastly different from the 15 or 18% that used to be talked about as a sort of natural top.

No single item is responsible for this improvement. It has been a matter of putting together a number of things; most of them are in the direction of facilitating delivery of adequate quantities of heat at high temperatures. Several years ago, oxygen-enriched flames were ballyhooed as the answer to all melting problems; however, it is now widely realized that the gain from such a use of oxygen is highest in a furnace that is not or cannot be operated at top efficiency on air. The over-all effect is of sharpened awareness of the potentialities of the conventionally operated furnaces. It is not intended to imply that flame enrichment is never really justified. Furnaces exist from which larger heats are required than can be melted satisfactorily with existing regenerator capacity; oxygen enables the production of more steel under the circumstances than could be obtained in any other way.

POSSIBLE FUTURE IMPROVEMENTS

Since the openhearth process is nearly 90 years old, it is permissible to inquire why it has taken so long to accomplish what has been accomplished and to speculate upon the things to be accomplished. The student of its history must be impressed by the dominantly empirical nature of its development and by the fact that tradition and whim, rather than reason, have often been the tools of the designer. Perhaps as good an explanation as any is that steelmaking was an art, with little interchange of information among its artists and artisans. The steelmaker did the best he could with what he had and, considering what he had, it is not especially surprising that there was considerable witch doctoring. A half century was to pass before there was real opportunity to attempt to apply the principles of mechanics and physics and chemistry in any organized fashion. Even then, progress was slow; there was no such thing as beaker experiments which could be translated to terms of full-scale operation. Furthermore, the steelmaker was justifiably suspicious; after all, the investigators had – and sometimes still have – some rather naive notions on the facts of steelmaking life. The situation has changed sharply within recent years; the steelmaker is eager for technologic improvement and technologists are likely to have a much more adequate understanding of his problems.

The distance to be covered by existing processes is suggested by the best thermal efficiencies of today, say 40% for the openhearth and 70% for the electric. Considering the unalterable thermodynamic fact that a regenerative furnace cannot operate at 100% efficiency, it is safe to say that both are better than halfway toward their goals. This means that further improvement is to be expected, but to no earthshaking extent.

The physical and chemical requirements of steelmaking are now well enough known to rough out mental schemes for the future. The inherent appeal of the converter principle as a high-speed refiner inevitably looms large in such thoughts; experiments in this direction are under way, but such is not the only possible course. Any sensible six-year-old would turn the job over to one of his Space Cadet acquaintances with full confidence that superatomic energy under control of a couple of pushbuttons can produce supersteel in great abundance. He may be right, at that! Meanwhile, with both economy and conservation demanding that a large fraction of total iron units be obtained from scrap, it is difficult to avoid the conclusion that the basic openhearth furnace occupies top position among tonnage steel producers for any reason other than that it truly belongs there. Those seeking to improve its performance, or that of other existing processes, are evidently in no immediate danger of technologic unemployment.

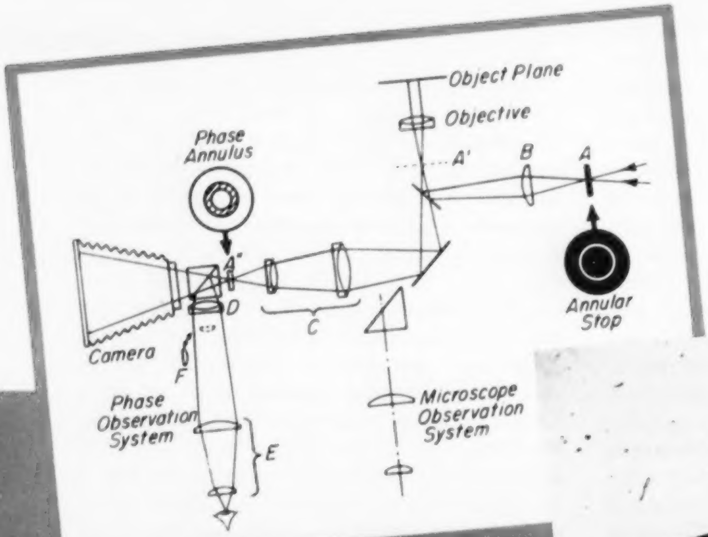


Fig. 1 – (Left) Optical Path for Phase Contrast Microscopy. Fig. 2 (Below) – The Same Field at 2500× of Austenite in Stainless Steel; Left Is Under Ordinary Illumination; Right Is Under Phase Contrast

It is a long cry from the days when some wag presented the late Albert Sauveur with a picture of a ginger snap and asked for an interpretation on the basis that it represented the microstructure of steel, and it is almost as long a cry from the days when many of us mistook polishing marks and etching pits for inclusions. Gone is the time when a simple micrograph at 50 or 100 diameters would tell us all we hoped to know about metal structure. Let us examine the present status of metal microscopy to see where we are, where we are going, and where we hope to go.

In such an examination we must bear in mind the true objective, namely, to learn how discrete particles of matter are located in relation to each other to produce a microstructure having specific properties. Many tools are used in conjunction with the microscope in this search for knowledge. Some of these are accessory to microscopy (for example, the electrolytic cell), others are accessory to the reasoning (for example, the X-ray and the Wheatstone bridge for measuring electrical conductivity), but in this survey we will restrict ourselves essentially to microscopy and things directly related thereto.

First, let us look at the instrument itself. Improvements in light source, lenses, supporting and manipulating mechanisms are obvious, but less obvious are some of the techniques which could not have been developed until such improvements had been made.

Phase contrast microscopy is a case in point. The phase contrast microscope has long been used in the examination of transparent materials in medical and biological fields. It has only recently been adapted to the examination of opaque objects – in particular, metals. Figure 1 shows the optical system. The essence thereof is the annular stop at A, and the phase annulus at A″. The annular stop gives a hollow cone of light, and the image resulting from the condensing, focusing, reflecting and projecting system is superimposed on the phase annulus plate at A″. The annulus carried by this phase plate has been coated with MgF_2 so that the direct light from the hollow cone which passes through it is advanced by a quarter wave length over the scattered light transmitted by the rest of the plate. This phase change of a quarter of a wave length results in major intensity differences in the image and corresponds to either small differences in level or variations in optical properties of the surface. In the usual metallurgical microscope, differences in level are not well brought out but the phase microscope produces shading so that good contrast can be obtained with differences in surface level of as little as 250 Å. Figure 2 shows austenitic stainless steel with ordinary and phase contrast techniques. The photographs speak for themselves.

With ordinary technique one might interpret grain boundaries and twin boundaries to be cracks. That these are not cracks is obvious from the phase contrast picture.

Let us consider another development in the instrument. The use of reflecting objectives is an old and honored practice in telescopy. It is only recently that this principle has been used in microscopy, primarily because it was not needed. As precision in observing phase changes and equilibrium conditions became more important, the need to examine metal specimens at elevated temperatures became apparent. Obviously, one cannot approach a red-hot surface closely with a glass or quartz objective without damage to the objective. Nor can one keep the necessary film of oil on a hot metal specimen. With the reflector, the distance from the specimen can be increased approximately tenfold. For example, to obtain a useful magnification of 500 × with an 8-mm., 0.5 N. A. objective lens, that lens must be brought to approximately 1.5 mm. from the specimen, whereas the reflecting objective with the same or even higher useful magnification limit can be about 15 mm. from the work. This extra working distance allows quartz or glass-shielded construction for keeping the specimen at a high temperature without unduly heating the reflector. Figure 3 diagrams such a system. Moreover, reflecting objectives are easily adjusted for changes in tube length or differences in optical path produced by glass or quartz windows.

Work in this country with the instrument in question has been limited, but in 1949 Keohane in Britain reported on the oxidation of molybdenum up to white heat using reflecting microscopes without loss of definition, and in 1951 Dewhirst and Olney, also in Britain, reported their work on the grain structure of iron and steel at temperatures up to 1830° F. using the same system. Figure 4 shows steel at 1740° F. and iron at 1350° F. In view of the great efforts made to retain high-temperature structures at room temperature so that they may be examined, it is obvious that this tool is invaluable and it is more than surprising that we, in this country, have not made greater use of it. It requires little gazing into the crystal ball – or shall we say the reflecting mirror – to predict a flood of such work in the next decade.

Metallography — New Instrumentation and Techniques*

The ultraviolet microscope, used as early as 1900 for biological work, was not applied for metallography until 1926, when F. F. Lucas redesigned it as a metallurgical microscope. It showed great promise as a research tool, but since its monochromatic optical system was designed for a single wave length of light (2750 Å), the difficulty in focusing with invisible light precluded its widespread use. More recently, Vilella, using an ultraviolet objective designed so that the two wave lengths, green (5460 Å) and ultraviolet (3650 Å), are simultaneously in focus, has obtained resolution, flatness, and depth of field superior to the best obtainable by visible light. The dichromatic properties of the objective make it possible to focus a specimen using a green filter with as-

*Presented at "Sauveur Night" of the Philadelphia Chapter, March 28, 1952.

By AUGUSTUS B. KINZEL, President, Union Carbide and Carbon Research Laboratories and Vice-President, Electro-Metallurgical Co., New York

surance that it will also be in focus with a filter transmitting at 3650 Å. The reflecting objectives, on the other hand, being achromatic over both the visible and ultraviolet spectra, may be focused with any desired wave length of visible light and the exposure then made with ultraviolet light of any wave length (including the extremely short ones) with a possible twofold gain in resolution over visible light.

Still another development in instrumentation is worthy of mention. We are all familiar with interference bands produced by minor but precise differences in effective length of light paths. Two optical flats pressed together, when viewed with monochromatic light, show straight but equally spaced fringes representing a small but constant distance of separation. If either of the flats is not optically true, the fringes will be irregular because of varying distance of separation. If we press an optical flat on a metal specimen and view the specimen with monochromatic light, we see similar fringes. When the specimen is smooth the fringes are widely spaced. When the specimen surface is irregular they are closely spaced and wavy. The effect may be enhanced by a coating of silver on the lower surface of the optical flat, in such a way that half the light is transmitted and half reflected. In practice, the specimen is set on a stage and carries such an optical flat. Figure 5 at left shows a specimen of babbitt metal viewed with the ordinary microscope. With the interference microscope the contour lines in Fig. 5 at right outline the projections of the copper-tin compound and antimony-tin compound. This method can detect differences in level of approximately 5000 Å, and in 1950 Tolansky in England reported on an interference microscope utilizing a multiple-beam technique which detects variations in level of approximately 25 Å.

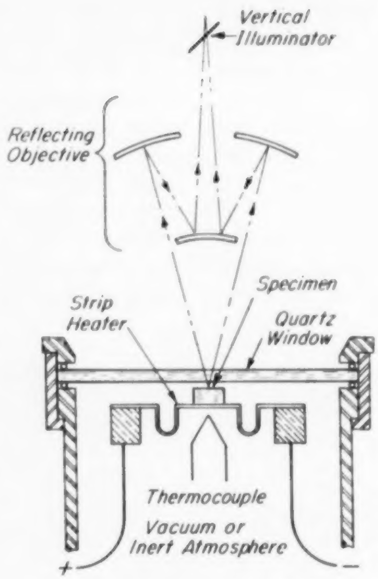


Fig. 3 – Arrangement of Reflecting Objective so Lenses Are at a Safe Distance From Hot Sample

Color metallography with and without polarized light, while not a new development in instrumentation, is just now coming into its own because of the availability of color film which can be processed in the average photographic laboratory. The techniques involved have been frequently described, and it is sufficient here to say that change in color with change in polarization (using crossed nicols) is invaluable in identifying particular constituents such as nonmetallic inclusions which have some transparency and are frequently anisotropic.

Graphite and certain carbides and silicides are particularly susceptible to this method of examination, and Fig. 6 shows the silicon (dark gray), calcium disilicide (flesh-colored), and iron disilicide (lavender) with ordinary light, and Fig. 7 the same field with calcium disilicide as two crystals, one red and the other blue, when viewed with polarized light.

These techniques are in constant use in our own laboratories and in many others and will certainly be widely used in the near future.

Specimen Preparation – No matter how good the instrument or the special technique of its use, the image can be no better than the sur-

Fig. 4 – Microscopy at High Temperature as Used by Dewhirst and Olney to Show Grain Structure. Left is steel at 1740° F., right is iron at 1350° F.

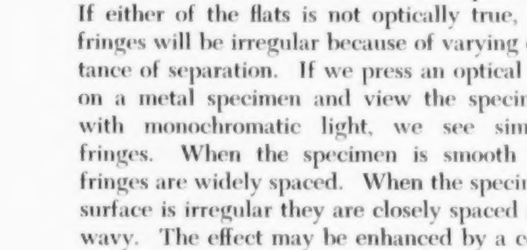
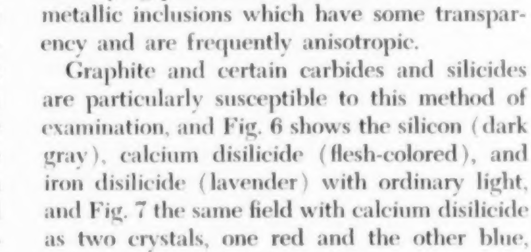


Fig. 5 – Left Is Babbitt Metal as It Appears Under Ordinary Illumination; Right Shows Contour Lines Representing Projections of the Cu-Sn and the Sb-Sn Compounds as Brought Out by Interference Microscopy



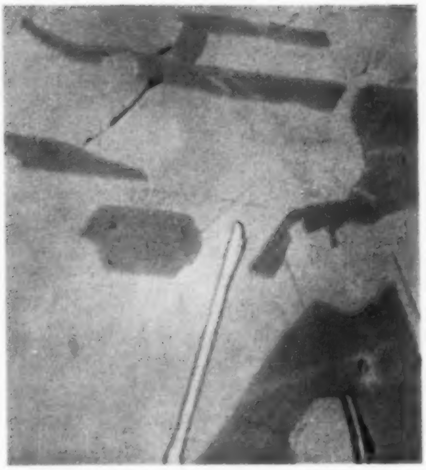


Fig. 6 – *Ordinary Light Shows Dark Gray Silicon, Flesh-Colored Calcium Disilicide, and Lavender Iron Disilicide*

Fig. 7 – *In the Same Field Under Polarized Light Calcium Disilicide Appears as Two Crystals, One Red, One Blue*

Differentiation of Carbides and Silicides in Calcium-Silicon Alloy by Color

face being viewed. Thus, a word is in order with respect to specimen preparation. Electrolytic polishing, introduced and first reported by Jacquet in France in 1935, is now in fairly wide use; smooth, scratch-free surfaces can be prepared by anodic attack in a fluid electrolyte on specimens previously polished mechanically to optimum degree. Its only disadvantage lies in the possibility of removing inclusions by attack or of bringing them out in bold relief if there is no solution.

REFINEMENTS IN POLISHING TECHNIQUES

While the basis of metallography lies in etching to secure relief, certain relief effects are bothersome and may obscure interpretation. These can be avoided by using diamond dust following the regular metallographic polish. Diamond dust of 1 micron maximum particle size is sprinkled on a Selvyt fabric-covered wheel and held there by paraffin oil. Any fine scratches left by the diamond dust are removed by a brief polish on a cloth-covered wheel carrying gamma alumina powder prepared by calcining – a preparation commonly known as "Linde B Alumina".

As to mechanical polishing, no one as yet has conceived of a satisfactory method. There is a real need for a cutting abrasive approaching the proportion of diamond dust but more readily available – a need that will doubtless be met in the foreseeable future.

One new idea – taper-section polishing – actually increases the useful magnification by as much as 25-fold. In this novel non-optical method the specimen is cut at a small, predetermined angle instead of perpendicular to the surface. The increase in magnification along a line in the plane of the angle normal to the apex of the solid angle is measured by the cosecant of the angle of taper – that is, a cut of 5° 43' gives a tenfold magnification along such a line but no magnification at right angles thereto. It is generally advisable to put a protective coating on the specimen approximating the same hardness as the specimen and have the angle cut through that coating. The method may also be used to study protective coatings themselves, and to obtain microhardness values close to the surface. Figure 8 on the next page shows the groove between two copper grains as brought out by taper-section polishing. Note the jog in the grain boundary. This groove is actually 5000 A across and only 700 A deep.

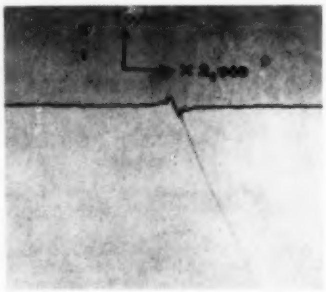
Etching as well as polishing techniques are being developed to uncover true structural details and avoid false structures or artifacts. Electrolytic etches, both anodic and cathodic, can be adjusted by variation of operating potential to show true conditions. Heat tinting and oxidizing reagents produce staining rather than etching effects; here again, control of conditions and degree of staining permit study of the true effect. Deposition of metallic films such as copper, silver or mercury is an old art that is being developed to a science and deserves much further study; it should find extensive application in the investigation of early stages of precipitation phenomena, where minor differences in composition or strain (affecting

Techniques for Electron Microscopy

the solution potential of the metal) will result in different degrees of staining or metallic film deposition.

The recent widely used method of cathodic etching by gas ion discharge deserves special mention, for it can reveal greater structural detail. Here atoms are actually removed from the specimen by the ion current of the glow discharge, which is preferably carried out in argon at something less than 30 microns pressure. Usually discharges are 3000 to 12,000 volts with ion currents of 5 to 20 milliamp. While tedious, the results usually are well worth the trouble.

Fig. 8 – Taper-Sectioning Gives Tenfold Magnification in One Direction. Note groove 5000 A wide and 700 A deep at copper grain boundary (Perryman)



Electron Microscope – The most spectacular recent development in microscopy has been the electron microscope. So much has been written about this that we may take it for granted that the basic principles are understood. Briefly, the electron beam serves as a light beam. It is refracted and reflected by virtue of electromagnetic fields which serve the same function as normal mirrors and lenses serve with respect to light. It gets its usefulness from the shortness of the wave length. The limit of the resolution of the light microscope with a wave length of about 5000 Å is 1750 Å; that of the ultraviolet microscope with quartz optics and a wave length of about 2500 Å is about 800 Å; that of the electron microscope with an effective wave length of about 0.05 Å under average conditions is about 100 Å, and under ideal conditions 20 Å or perhaps even 10 Å with selected test objects. Even 200 Å resolution is ten times that of the best optical systems.

As yet we have not used its full resolving power in metallography because of limitations in preparing specimens and replicas. With present techniques the electron beam must be used with transparencies, obtained by making very thin replicas of the surface. These techniques are being constantly improved and I would refer to this year's Howe Memorial Lecture as illustrative of recent progress. Many fine electron micrographs have been shown in recent metallographic exhibits at the ASM's National Metal Congress and Exposition.

In the next decade we can also expect new techniques, particularly for direct examination of the metal surface. How this will be done we do not know, but as researchers we can be reasonably sure that it will be done.

The electron microscope is particularly adapted to study colloidally dispersed particles or thin grain-boundary films, and we may well expect it to shed light on such phenomena as temper brittleness in steels, the effect of boron on hardenability, and the production of fine-grained and abnormal steels by addition of aluminum.

That the electron microscope is a powerful research tool has been amply demonstrated by results already obtained on age hardening of aluminum-copper alloys, on chromium carbide precipitation in stainless steel, carbide particles and transformation structures in steels, and resolution of the isothermal transformation products in eutectoid steel at the knee of the S-curve. The last-mentioned products, formerly called "nodular troostite", have been shown to be fine pearlite with a minimum lamellar spacing of about 300 Å – well below the limit of resolution of the light microscope.

Application of electron microscopy to particles extracted from metal specimens is a field in itself but a most useful means of furthering our knowledge. The same techniques have been applied to nodules of graphite in nodular iron, carbides of chromium, vanadium, and molybdenum in heat treated steels, nickel boride in nickel-bearing alloys, complex carbides of the M_6C type in the titanium, columbium, or tantalum-bearing austenitic stainless steels, and iron-chromium oxide in high-chromium steel.

These techniques have also been used for the isolation and determination of sigma phase in stainless steels and of a newly discovered iron-molybdenum-chromium compound in austenitic steels which is almost indistinguishable from sigma phase by other means. In this way we have been able to produce working equilibrium diagrams of complex alloy systems, in particular the stainless steels containing carbon, chromium, nitrogen, nickel, manganese, cobalt, molybdenum, vanadium, columbium, and tungsten; the cobalt-chromium-base alloys (Stellite alloys) with carbon, tungsten, molybdenum,

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nickel and iron; and the nickel-base alloys (Hastelloys) containing molybdenum, chromium, silicon, carbon, and boron.

Summary and Prognostications – Several new tools for microscopy have been described herein. Each of these advances is behind us and it only remains for us to put them to sufficiently general use. The merits speak for themselves so that we can readily predict that such general use will result in a relatively few years. In particular, the reflecting microscope could be used in conjunction with a sequence moving picture camera to actually observe precipitation phenomena or phase changes not involving large local volume changes.

At present, with the optical microscope, the limit of resolution with visible light is about 2000 A, with ultraviolet light about 1000 A, and with the electron microscope about 100 A. The order of magnitude of the lamellar spacing of the finest pearlite is about 1000 A – that is, several hundred atoms – and the smallest stable crystal nucleus that we would expect to occur in a metal would also comprise a group of several hundred atoms. To resolve such particles, a limit of resolution of some 10 to 20 A is necessary, and this is not far from the 100 A now available – particularly when we remember that the electron microscope is capable of giving such resolution and that it is only our failure to solve the problems of sample preparation which sets the limit.

With the tools already available or readily foreseeable, the metallographer, in the not too distant future, should be able to examine all structures resulting from precipitation and transformation reactions in alloys. But our thinking must not stop at this point. New tools are on the horizon. The use of radioactive tracers in microscopy is a case in point. The techniques have already been used at low magnifications. The replica system would seem to be particularly advantageous in such a field. Already much progress has been made with auto-radiographic films on histological specimens, and work on similar treatment of replicas is under way. These emulsions would be chemically activated by emanations from the radioactive tracers. Other work conceives of incorporation of fluorescent materials in the replicas, and these, too, would be activated by the tracers.

We have come a long way since the early difficult years when Albert Sauveur brought metallography to a high state of art. Professor Sauveur thought of himself primarily as a metallographer, and we of the Union Carbide & Carbon Research Laboratories and the Electro Metallurgical Co. feel a great debt to him and still believe that the microscope is the most important single tool to help in the understanding of metals.* Advances in metallographic techniques will go on, and the gap between the crystal and the atom, as it were, will be ever narrowed. By using this new knowledge we will be able to realize more fully the strength, ductility and toughness that are inherent in our metallic materials.

*One of the most famous metallographers of our time, José Vilella, made his initial reputation at our laboratories, and William Forgeng, another of such famous metallographers, is now in charge of our metallographic laboratory. Others of our staff to whom I would particularly like to express appreciation are Arthur Lytle, director of research, Walter Crafts, associate director of research, and David Swan, assistant director of research, Union Carbide and Carbon Research Laboratories.

Postwar Progress

Belgium, the Netherlands, and the Grand Duchy of Luxembourg, called together "Benelux", possess, in the heavy iron and steel industry, outputs and capacities given in Tables I to III. It will be seen that most of the producing industry is in Belgium and the Grand Duchy of Luxembourg, which have in fact been merged in an economic union with a common export policy since 1922.

Raw Materials – Belgium has coal deposits of its own. Coking coal has been produced in the Campine basin, and, during the past 20 years, the heavy industry has built its own coking plants to meet blast furnace requirements. The Netherlands also has its own coking coal and coke ovens. On the other hand, Luxembourg industry, having no coal deposits and no coking plants, is dependent upon imports of these materials from Germany, Belgium and the Netherlands.

The basis of the heavy iron and steel industry in the B-L economic union is the iron ore deposits of French Lorraine and the deposits located in the Grand Duchy (an extension of the French ore field). The use of the basic bessemer process was indeed determined by these deposits of high-phosphorus iron ores, originally called "minettes". The Lorraine ores are rather low in iron content, and give much fines and flue dust, but are highly reducible.

Belgium has no iron deposits within its own borders except in the extreme southern part, where some siliceous ore is located at Halanzy.

In Luxembourg, the western deposits are mainly siliceous and the eastern mainly calcareous. Their iron content is 26 to 32%, and this is inferior to the French minette ores of the Briey basin in Lorraine. Likewise, the silica content of Luxembourg ores is higher and for that reason it is more economical to run an acid burden in the blast furnace.

For blast furnace smelting, Belgian steelworks now use mainly calcareous or basic minette ores from France, with an addition of siliceous ores from Luxembourg to correct the index of basicity to an average ratio CaO/SiO = 1.5 in the slag. To enrich the burden, high-grade magnetite from Sweden may be used. The trend in recent years has been to produce the maximum amount of pig iron with the minimum of coke. Hence the use of very large quantities of scrap in blast furnaces.

Annual production of Thomas pig iron is consistently slightly higher than the total output of Thomas steel. This is a condition which differs from the steel industry in the United

Table I – Net Tons Pig Iron and Ferro-Alloys Produced in 1951

Locality	Blast Furnaces		Production (Tons of 2000 Lb.)		
	Existing	In Blast	Ferro-Alloys	Thomas Pig Iron	Total
Belgium	52	49	246,000	5,099,000	5,345,000
Luxembourg	32	27	–	3,481,000	3,481,000
B-L Economic Union	84	76	246,000	8,580,000	8,826,000
Netherlands	3	3	–	577,000	577,000

By ACHILLE G. LEFEBVRE, Professor, Polytechnic Institute of Mons, Belgium

and Trends in Steel Manufacture in the Benelux Region

States, where the blast furnaces had on Jan. 1, 1951, a total capacity of 72,500,000 net tons of pig iron and ferro-alloys, as against a total capacity of 104,500,000 net tons of crude steel (openhearth, bessemer, electric and castings).

Rehabilitation of Plants – Equipment of the steelmaking industry somehow remained more or less intact throughout the second world war, but after the war steel companies completed programs of modernization and re-equipment, the principal aims of which were as follows.

In the blast furnace departments:

A. Rebuilding individual furnaces to the larger capacity of 400 to 500 tons daily, with an iron yield of about 32% on poor ores.

B. Construction of ore dressing plants for crushing, screening, sizing and sintering the fine ores by rotary kilns or sintering in Greenawalt or Dwight-Lloyd machines, feeding the sintering plants with blast furnace flue dust (iron content, 32 to 35%), iron ore fines (about 32% iron with poor ores), and sometimes purple ore and mill scale.

C. In Belgium – and in the Netherlands also – new coking plants were required to provide adequate supplies of metallurgical coke for the blast furnace. Additions were made to power stations supplying one or more works, for better utilization of coke oven and blast furnace gas.

In the Thomas (basic bessemer) steelworks:

A. Increasing the capacity of the mixers and converters.

B. Construction of oxygen plants for oxygen enrichment of the air blast into bottom-blown basic converters.

In the openhearth steelworks, developments were slow; there have been some increases in furnace capacity. In Belgium the scrap process is used exclusively, but the scarcity of good melting scrap limits production. In most openhearth steelworks, fuel oil was substituted for producer gas or coke oven gas.

In the electric steel departments progress, again, is slow. Belgium and Luxembourg have no large electric steelworks, because they have no water power resources like France and Italy which can produce low-cost electricity. It might be mentioned that several of the large works use the basic electric furnace in duplex

Table II – Production and Capacity for Crude Steel (Net Tons)

Locality	1951 Production	Capacity (Jan. 1, 1952)	Per Cent World's Capacity	Estimated 1953 Production
Belgium	5,516,000	5,787,000	2.33	6,064,000
Luxembourg	3,393,000	3,582,000	1.44	3,529,000
Netherlands	610,000	640,000	0.26	882,000
Total	9,519,000	10,009,000	4.03	10,475,000
World	230,512,000	248,531,000	100.00	266,233,000

Table III – Crude Steel by Process, 1951

Locality	Thomas (Basic Bessemer)	Openhearth	Electric	Bessemer (Acid)
Belgium	85.3%	12.2%	2.5%	–
Luxembourg	nearly 100.0%	–	–	–
B-L Economic Union	90.0%	7.5%	2.5%	–
Netherlands	–	nearly 100.0%	–	–
World	15.0%	75.0%	4.5%	5.5%

with the Thomas converter to increase the output of special steels. Such steelworks are increasing their furnace and transformer capacity.

Recently, an important steel plant near Charleroi, specializing in the rolling of plates, has ordered from the Pittsburgh Lectromelt Furnace Corp. an electric arc furnace with swinging roof having a diameter of 24 ft. and a capacity of 140 tons – among the largest in the world. The A.C.E.C. Charleroi will supply the electrical equipment, including a transformer of 30,000 kva. The electrical demands of this one furnace have posed a special problem for both the generating network and the manufacturer of the electrical equipment.

In steel foundries, high-frequency furnaces are being installed for the manufacture of high-alloy castings.

In the rolling mill departments, modernization and re-equipment have proven to be the most important and most expensive part of the entire program.

Increased emphasis on flat products caused the large steel companies to install new rolling mills with the help of experienced American constructors – Mesta, United, Morgan, Continental, Mackintosh-Hemphill. These included blooming, slabbing and four-high plate mills, a semicontinuous hot strip mill, a Steckel mill, a Morgan wire-rod mill, continuous mills for wire and hoops, and a cold reduction mill to feed an electrolytic tinning line.

The Ferblatil Cy plant near Liège, Belgium, manufacturing tin-plate, now has the first continuous electrolytic line on the continent. It is a model of its kind.

These new rolling mills have increased the percentage of flat products in relation to total rolled products, as shown in Table IV. The proportion of flat products in the total steel output will increase by about half and reach 40% in the near future. In comparison, it may be stated that in 1950 the production of flat products in the United States (plates, coils, sheets, strip and skelp) reached 53% of the total production of hot rolled products (39,800,000 net tons out of a total of 74,800,000).

Table IV – Production of Finished Steel; Net Tons in 1951

Locality	Wire Rods and Shapes	Strip, Plates and Sheets	Semi-Products	Total Hot Worked Products	Flat Products in Percentage
Belgium	2,564,000	1,694,000	246,000	4,503,000	37.6%
Luxembourg	2,047,000	431,000	304,000	2,783,000	15.4%
B-L Economic Union	4,611,000	2,125,000	550,000	7,286,000	29.1%
Netherlands	144,000	324,000	22,000	491,000	66.0%

IMPROVEMENTS IN PROCESSES AND QUALITY

As pointed out above, a large amount of the crude steel produced in Belgium and Luxembourg is steel manufactured in Thomas plants, the phosphorus content of the minette ores in the blast furnace burden making the pig iron particularly suitable for the basic bessemer process. This process accounts for 85% of the Belgian steel production and nearly 100% of the Luxembourg production. (See Table III.) Under "normal" economic conditions it has the lowest production costs.

The problem of continuously improving the quality of Thomas steel is the first important specific and vital problem which has emerged during the past 20 years. Methods have been developed on an industrial scale since the war.

Among the new ideas and the different solutions which have brought economic and technical improvements we should note:

A. Preparation of blast furnace charges by more general use of ore crushing, screening, sizing and sintering of fines in order to smelt a more suitable burden. The use of crushed, screened ores and the addition of agglomerates in the blast furnace charge provide a more homogeneous burden and lead to sizable increases in the yield. An important outcome of this technique is lowered coke consumption, reaching 350 to 450 lb. per ton of pig iron in some Luxembourg steel plants.

B. A pig iron of better physical and chemical qualities has been produced by desulphurization and refining operations after smelting in the blast furnace.

With a burden composed mostly of minette ores, the analysis of basic pig iron tapped from the blast furnace will fall within the following

limits: silicon, 0.30 to 0.45%; manganese, 0.60 to 0.80%; phosphorus, 1.80 to 2.00%; sulphur, 0.10 to 0.08%.

Desuphurization of this liquid pig iron is now carried out in the ladle in all the Thomas steelworks of Belgium and Luxembourg, as well as in France, the Saar and Germany, by using commercial sodium carbonate which is sold under the tradename "Special Heavy Soda Ash M". In addition to the chemical reactions which reduce the sulphur content to less than 0.04%, this treatment with Na_2CO_3 has a powerful cleansing action, thanks to the stirring effect of the rapid evolution of carbon dioxide gas. The treated liquid pig iron is thus made more fluid and its steelmaking quality is improved.

C. Content of phosphorus and nitrogen – the two harmful elements in basic bessemer steel – has been lowered.

In the conventional operation of bottom-blown converters with air blast the average basic bessemer steel will contain 0.06% phosphorus and 0.015 to 0.020% nitrogen. These are residuals, after some interesting and rather complex chemical reactions have taken place between the various constituents of pig iron and air (21% O_2, 79% N_2) at the existing high temperatures in the converter. Now let us examine briefly these chemical reactions.

The impurities of the liquid pig iron, poured into the converter with burnt lime and a little scrap, are oxidized in the converter in the following order: Silicon, manganese, carbon, phosphorus.

This is illustrated by the various curves shown in Fig. 1. Since the equilibrium constant

$$K_{Mn} = \frac{[Fe]\,(\Sigma MnO)}{(\Sigma FeO)\,[Mn]}$$

decreases as temperature increases, some manganese goes back to the bath toward the end of the blow when temperature rises sharply during the "overblow" (period CDEF on the time scale in Fig. 1). This manganese from the slag acts as a deoxidizer:

$$FeO + Mn \rightleftarrows Fe + MnO$$

To avoid oxidation and loss

of iron it is necessary to stop blowing when phosphorus is about 0.06%.

Two facts are well known, first that the phosphorus reaction

$$2\,P + 5\,FeO = P_2O_5 + 5\,Fe + \text{heat}$$

is a very exothermic reaction, and is thus promoted at a lower temperature.

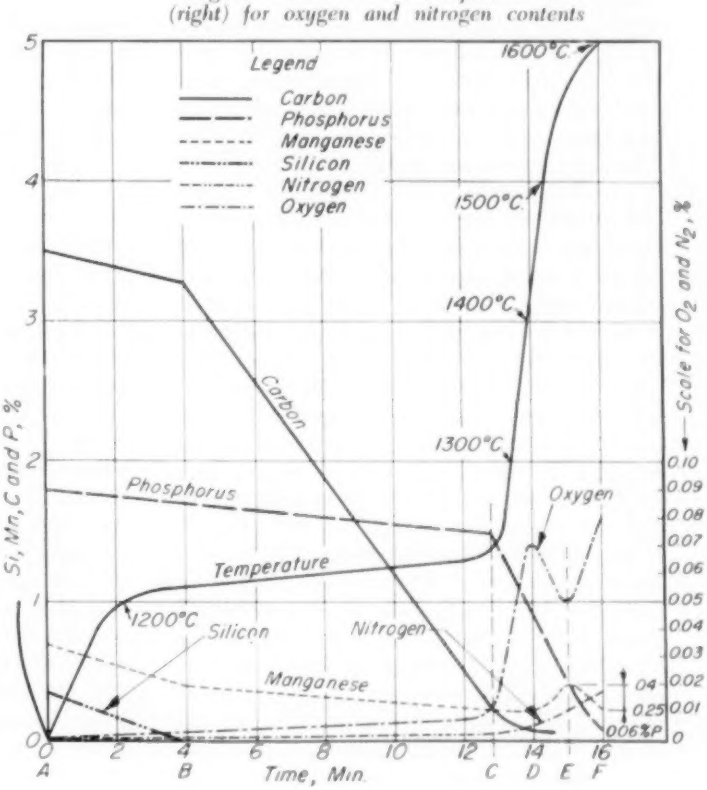
Second, that the nitrogen content of the bath increases with the temperature. Saturation of nitrogen at different temperatures is as follows:

0.0445% N_2 at 1560° C.
0.0476% N_2 at 1665° C.
0.0510% N_2 at 1750° C.

The practical problem therefore is to balance the two effects; phosphorus must be eliminated, but its oxidation generates so much heat that undesirable nitrogen is absorbed from the air blast. An obvious solution would be to "afterblow" with pure oxygen, but would it not be far too expensive?

An alternative of keeping the temperature down was tried in the years between the two

Fig. 1 – Log of Operations of a Typical Thomas Converter. Temperatures are shown alongside the curve. Note expanded scale (right) for oxygen and nitrogen contents



Oxygen for Thomas Steel

wars by application of the so-called "HPN steel process", which added pure iron ore, rolling mill scale and scrap during the overblowing period. This gave rimming "HPN Thomas steels" with sulphur less than 0.035%, phosphorus about 0.040%, and nitrogen 0.012%.

This was a step in the right direction, so in the postwar period experiments were undertaken by the National Bureau of Metallurgical Research (Centre National de Recherches Metallurgiques, C.N.R.M.) under direction of Prof. Pierre Coheur of Liège. Extensive studies were made by different steelworks in the Liège and Charleroi Basins and in Luxembourg to ascertain the optimum conditions for eliminating phosphorus and nitrogen. The studies were briefly described by M. Coheur in his contribution to the World Metallurgical Congress sponsored last year by the American Society for Metals, a paper published by *Metal Progress* in October 1951.

By blowing with oxygen-enriched air (28% oxygen, 72% nitrogen), or even by blowing with a mixture of oxygen and steam instead of air, and by using a second soda slag, it is now possible to get on a large industrial scale basic bessemer steels with exceptionally low phosphorus (0.03% or lower) and also low nitrogen (0.008% and lower).

The physical properties – especially the ductility – of these Thomas steels produced by the combined "second soda slag plus oxygen" method are much improved, and as good as those of normal openhearth steels, either basic or acid.

Several Belgian and Luxembourg steelworks are now being equipped with oxygen plants of 100 to 150 tons daily production to use oxygen-enriched air in this way on a large scale. These new oxygen plants, entailing very high capital expenditure, will start at the beginning of 1953 to produce the first "oxygen Thomas steels".

THE LOW-SHAFT FURNACE

In view of future possible shortages of high-grade raw materials – good coking coal or metallurgical coke and good lump ores or agglomerates – for increased pig iron production in large, modern blast furnaces, a considerable interest is being directed toward the use of lower grade fuels (such as poorly coking or noncoking coals) and inferior fine ores. These would produce pig iron in a furnace with a shorter shaft blast and oxygen-enriched air to get a lower temperature at furnace top and to produce gas with a relatively high thermal value.

In 1951, with the approval of the Organization for European Economic Cooperation (O.E.E.C.), a directing committee for international research on low-shaft blast furnaces was appointed, composed of representatives of seven countries, Austria, Belgium, France, Greece, Italy, Luxembourg, and the Netherlands. Battelle Memorial Institute of Columbus is also a member of this committee.

Henri Malcor, the President of I.R.S.I.D. (Research Institute of the Steel Industry of France), is chairman of this committee. Its scientific management is the responsibility of the C.N.R.M. Liège (in the person of Pierre Coheur). Financial assistance is also given by the Belgian research organization I.R.S.I.A. (Institut pour l'Encouragement de la Recherche Scientifique dans l'Industrie et l'Agriculture).

The "international" low-shaft furnace for an output of 80 tons a day has been designed and is now being built near a large steel plant in Ougrée-Liège, which already has an oxygen plant. This pilot furnace will be ready for operation in 1953.

SUMMARY

The researches carried out in these recent years and their considerable results, having large industrial possibilities, are due to the C.N.R.M., which has united in a common effort the research work of all the Belgian and Luxembourg steelworks.

It must also be pointed out that the achievements and the prosperity of the heavy steel industry in Belgium and Luxembourg can be attributed entirely to the initiative of private enterprise.

Belgium, the Netherlands and Luxembourg are now integrated with three other countries, France, Germany and Italy, in the coal and steel community known popularly as the Schuman Plan. It is certainly to be hoped that the High Authority of the Schuman Plan may in the future impose no controls or restrictions which may paralyze this necessary freedom of private enterprise.

Resurrection of Metallurgy in Italy

In order to give a clear idea of the vicissitudes of the Italian metallurgical industry, it is necessary to sketch the prewar situation. Schematically it is shown in Fig. 1. In 1938 Italy produced 2,640,000 tons (of 2000 lb.) of steel, 1,100,000 tons of pig iron, 33,000 tons of aluminum, 46,000 tons of lead, 37,500 tons of zinc and 2500 tons of mercury. Supporting this industry we could mine only 1,080,000 tons of iron ore, 880,000 tons of iron pyrite. We were very short of fuel, mining only 1,550,000 tons of coal and lignite, and requiring us to import about ten times that (14,300,000 tons), much to the detriment of our trade balance.

The importance of metallurgy to the Italian economy is measured by the fact that the iron and steel industry employs about 60,000 men, but – more important – supplies the mechanical industry and its 600,000 workers.

War Damage – World War II destroyed about one third of our national wealth; metallurgical works at the end of the war could produce less than one sixth the prewar amount.

Postwar recovery was hampered by many circumstances. In the first place, we find the practical disappearance of our merchant fleet, tremendous damage to communications, and destruction of bridges – even the complete removal of some railroad lines. In the second place, the political and economic setting of Europe looked very uncertain.

Nevertheless, we did what we could with what we had. Welding was the prime tool, and was used widely for such things as repairing irreplaceable machines and reassembling mill machinery broken by dynamiting. Emergency repairs thus put the less damaged plants back into production. In that period we seriously lacked concrete reinforcing rod, iron sheets and tin-plate, all of which were costly.

Furthermore, the pressure of our population (one of the densest of the world, reaching nearly 400 inhabitants per square mile) and acute widespread unemployment, fictitious employment of a lot of workmen who remained in the works because of social and political pressures without actually producing anything, the reduction of public revenue to about one tenth of that before the war, political troubles and the disorganization of the whole structure of the State – all these have had serious influences on the reconstruction program.

At the same time, the purchasing power of money fell to about one fiftieth of its value before the war. The time lag between devaluation and rise of wages caused social troubles, which often took a political turn, such as occu-

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pation of factories and the expulsion of executive personnel disliked by the laboring men.

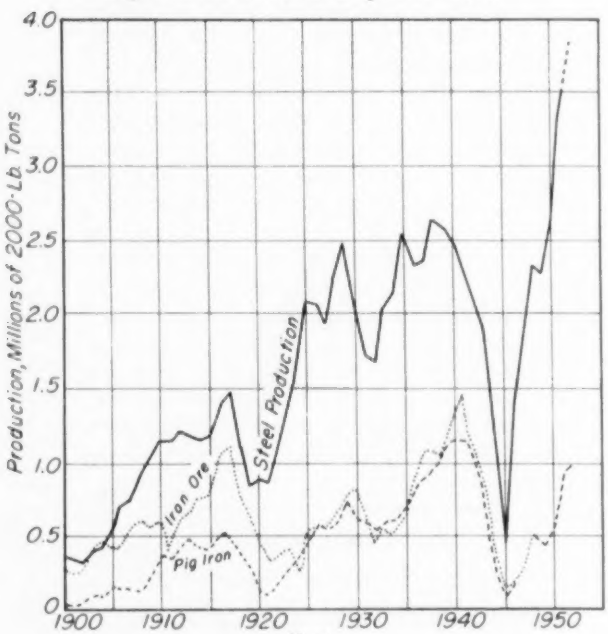
Hence it was that the first positive program for reconstruction of the Italian metallurgical industry did not appear until late in 1948. A prime fact to reckon with was that the per capita consumption of steel is very low – 130 lb. in 1938 – in comparison with 830 lb. in the U.S.A., 580 lb. in Great Britain, and 350 lb. in France. It was fairly safe to assume, therefore, that Italy would match the expected expansion of the world's steel industry, namely double every 20 years.

As a result of such considerations, a steel production of 3,850,000 tons was scheduled as a goal to be reached in 1953, and rebuilding programs were proportioned according to this figure.

Our prewar iron and steel industry was based mainly on scrap remelting, primarily because such plants were more economical than integrated plants. Many little openhearth and electric steel works existed, often connected with small rolling mills, forging shops and mechanical industries. In those times, foreign scrap supply presented no difficulties, but after the war, steelmaking countries all over the world had to utilize their own scrap and even competed for foreign scrap.

It was therefore impossible to rebuild an Italian iron and steel industry depending mainly on scrap

Fig. 1 – Annual Production of Iron Ore, Pig Iron and Steel in Italy Since 1900



imports, but on the basis of past experience the amount of raw materials available at home could be evaluated as follows (in tons of resulting steel):

Scrap recovered from machining and steelmaking operations		1,050,000 tons
Scrap recovered by collection and dismantling		400,000
Various iron ores	600,000	
Pyrite cinders	500,000	
totaling	1,100,000, and	
corresponding to iron for about		550,000
Total		2,000,000 tons

In order to integrate our requirements for a 1953 production of 3,850,000 tons, iron for 1,850,000 tons of steel must be imported, either as scrap or ore.

While this amount of scrap might be secured abroad, it would be wise to build plans which can produce steel from ore. As shown by the map, Fig. 2, there are fine deposits of ore in the Mediterranean basin, geographically very near our projected blast furnaces. These plants are on the west coast, except the two small furnaces at Aosta in the north which are near a good magnetite deposit. Reserves of these deposits are fairly high, extending to several centuries at the anticipated rates of production. (See Table I.)

It is therefore very logical to base the new Italian iron and steel industry upon such nearby deposits.

Fuel – Italy has had to import all its coking coal and most of the fuel used for domestic and manufacturing purposes. This has been a burden for our iron and steel industry, but it is counterbalanced by the fact that other countries of Europe – though having cheaper coal because they have the mines – must also use local ores which, being much poorer, require high fuel consumption. European blast furnaces use 1900 to 2100 lb. of coke per ton of pig iron produced. Alternatively they can import rich ores from distant deposits.

In Italy, which is near to rich ore deposits, coke consumption is about 1600 lb. per ton of pig iron (and it is hoped that this figure can be decreased). This difference in coke consumption largely counterbalances the cost of coal transported from greater distances.

But, fortunately, a new source of heat energy was discovered in Italy three years ago, namely, natural gas.

As far as purely thermal uses are concerned, we have now proved to our own satisfaction that it is possible to substitute

methane for coal. As to ore reduction by methane instead of coke, the problem is under study; its solution is for the future and will have, if any, a gradual application.

The reconstruction of the Italian iron and steel industry, therefore, while based on a considerable amount of foreign raw materials secured at fair prices, turned itself toward the concentration of the destroyed works into a smaller number of plants, with up-to-date equipment, and designing these new plants so that they may produce steel either from scrap or from ore in the most economical manner according to market conditions. The present main problem is to produce at costs equal to those of other steel-producing countries, in order to avoid the harm which costly materials would do to our mechanical industries.

The most remarkable achievements in the modernization of our iron and steel industry are undoubtedly the major integrated plants, which

Table I – Iron Ore Reserves of Mediterranean Basin

Country	Short Tons	Iron Content
Spain	800,000,000	50 to 52%
Spanish Morocco	50,000,000	62 to 65
French Morocco	65,000,000	45 to 50
Algeria	400,000,000	50 to 55
Tunis	100,000,000	50 to 55
Italy	40,000,000	45 to 55
Yugoslavia	700,000,000	50

are now being reconstructed or expanded toward the following annual production:

Bagnoli (near Naples) – 440,000 short tons of pig iron and 400,000 tons of steel billets, bars, and small rolled products.

Piombino (midway between Rome and Genoa) – 275,000 tons of pig iron and 300,000 tons of steel, consisting principally of rails and railroad materials.

Cornigliano (Genoa) – 475,000 tons of pig iron and 650,000 tons of steel plate, strip and sheet. The ultimate aim is to produce 1,100,000 tons of steel.

At the Bagnoli plant the steelworks has been put again into operation, with four 60-ton openhearth furnaces, four 30-ton basic bessemer converters, blooming and 6-in. billet mill; a continuous rod mill will be put in operation.

At Piombino a new steel plant is under construction, with three 150-ton openhearth furnaces, a new 45-in. blooming mill, and a remarkably modernized rail mill.

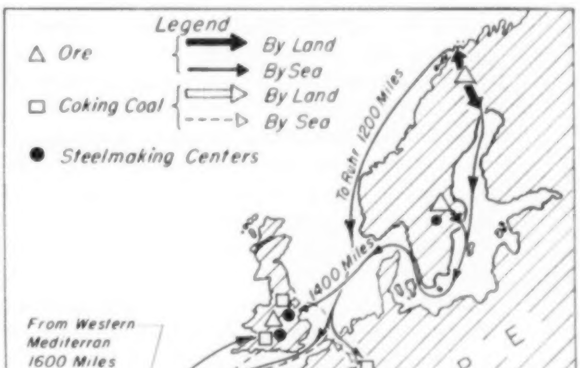
The Società Dalmine, which produces yearly about 260,000 tons of seamless tubes by the

Mannesmann process, has improved its works as follows: Steel ingots are now press-punched instead of roll-pierced, and then passed through the skew rolling mill, thus securing tubes of uniform wall thickness. All the reheating furnaces have been replaced by the rotating-hearth type, methane heated, fully mechanized and automatically controlled, thus obtaining considerable economy and a greater uniformity.

The old steel department of Torre Annunziata has been discontinued, but the plant is being equipped with up-to-date facilities for wiredrawing, rope making, and wire products manufacturing. The steel department and rolling mills of Bolzaneto have been closed, as well as the rolling mills of Voltri and of Sestri.

The most remarkable progress has undoubtedly been at the new Finsider steelworks of Cornigliano, which will be described in greater detail, because it illustrates the world-wide evolution in the manufacture of steel sheet, from manual operations up to continuous rolling mills. The over-all result of this evolution is striking, as is well known.

Fig. 2 – Map Showing Principal Ore and Coke Resources and Movements to Steel Centers of Postwar Europe



Nonferrous Metals and Alloy Steels

Steel sheet, which 25 years ago comprised less than 30% of total rolled production, has now risen to 55%. Cold rolled sheet, which in 1925 cost twice as much as rolled bar, costs now about 20% more than bar.

The new Cornigliano plant is planned so as to market this product at a low price. To do this only a large, integrated, modern plant will suffice. Construction of such a plant, which was planned in 1937, was already in an advanced stage in 1943. During the last years of the war, however, it was dismantled and most of the equipment taken away. Now it has been rebuilt with American help. Portions of the plant as it appeared late in October 1952 are shown in the halftone on page 89.

Located at a suburb near the protected harbor of Genoa, the plant is well situated to receive ocean-borne raw materials and to ship products over the national railway system. The site itself was shoreline, back filled for an area 5000 ft. wide by 6500 ft. long. Nearby rough ground furnished the necessary 6,500,000 cu.yd. of earth and rock, and at the same time was smoothed out to accommodate a previously planned housing project for plant personnel and others.

At the present time the plant contains a 56-oven coke plant with appropriate means of byproduct recovery; two blast furnaces each of 600-ton daily capacity (one now in operation); five 200-ton openhearth furnaces, a 2-high, reversing, slabbing mill; a universal rolling mill, 4-high, for plates 118 in. wide; six continuous 4-high mills for hot rolled sheet with all necessary auxiliaries. Speed of the latter mill will be about 2000 ft. per min. and its over-all length is about 1 km. (3280 ft.). In the cold finishing department will be found a 4-stand continuous mill for producing 80-in. sheet and tin plate at 65 tons per hr.; a 4-high reversing stand for sheets 40 in. wide, a continuous pickling line, annealing furnaces, and tinning and galvanizing departments.

It is anticipated that construction will be so far advanced by the early spring of 1953 that most departments will be in operation, and delivery of hot rolled coils or cold rolled sheets of various finishes can start.

The general effect of such reconstruction and new production can as yet only be indicated, as shown by the dotted extension of the topmost line in Fig. 1.

Figure 3 shows the laudable recovery of nonferrous production in Italy since the black days of 1945. Generally speaking, we are about at the same place we were at the beginning of World War II.

In the production of alloy steels, first mention should be made of Società Cogne, where production is concentrated on high quality and alloy steels. It receives most of the necessary ore from a local magnetite mine. Pig iron is produced by blast furnaces and electric furnaces. The steelworks consists of acid bessemer converters, acid electric furnaces and a half-dozen high-frequency induction furnaces, one of which handles 10-ton heats. Total pig iron production amounts to 175,000 short tons and steel production equals 330,000 tons yearly.

Table II – Data for Openhearths on Natural Gas

Item	100% Gas	80% Gas, 20% Oil
Number of heats	611	609
Average heat	34 tons	33.9 tons
Total production	20,762 tons	20,654 tons
Time per heat	6 hr., 18 min.	5 hr., 48 min.
Production per hr.	5.4 tons	5.8 tons

Firing with 80% gas, 20% oil uses 2.6% more heat units per ton of steel than when using 100% gas, respectively 4,740,000 and 4,620,000 B.t.u. per short ton.

Terni steelworks, which was built more than 60 years ago for producing armor plate, ordnance and projectiles, was badly damaged in the war and is now completing reconstruction. It will turn out quality steels and irons from electric furnaces. Noteworthy is the transformer iron sheet produced.

This steelworks has long used oxygen for refining; it is received under pressure through a pipeline from a neighboring plant. Total steel production has been brought to 155,000 tons yearly.

SIAC (formerly Ansaldo) Steelworks is also turning from war production to quality steel along lines similar to those just mentioned. Particularly they specialize in the manufacture of high-elastic-limit steels, forgings and special castings.

The Società Ilssa-Viola, which shortly before the war had started the production of special and stainless sheets, has fully resumed. This plant also employs oxygen for refining steel and obtaining low-carbon stainless steels. The Fabbrica Italiana Tubi, which also suffered heavy damage, has now brought its production up to double that before the war, production of tubes being now on the order of 27,500 tons yearly.

Italian Research Projects

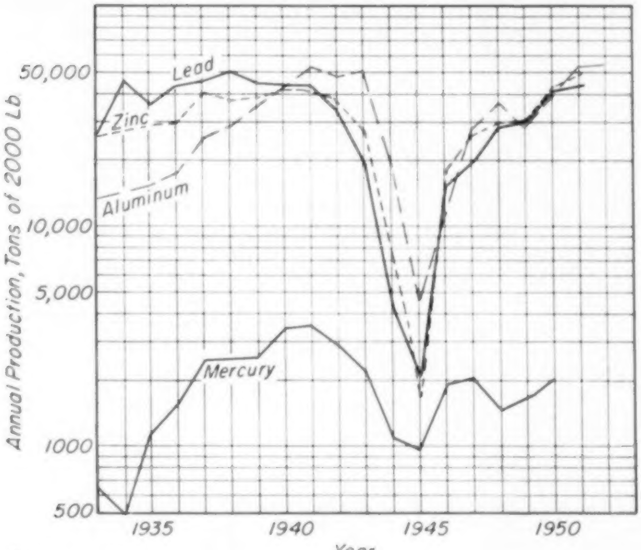


Fig. 3 – Italian Annual Production of Mercury, Lead, Zinc and Aluminum, 1933 to 1952. Note logarithmic vertical scale

To give an idea of the importance natural gas has acquired for Italian economy, it is sufficient to say that present production capacity will replace 75% of the coal importations. In other words, the savings that could be made by full utilization of available methane would equal 30% of the deficit in the Italian trade balance for the year 1951.

As soon as the first gas well came into production, Dalmine steelworks started its experimental use for openhearth furnaces, using gas compressed in cylinders, with such success that a pipeline was quickly laid. Now the whole plant is operated with methane as fuel, consumption in 1951 being 1990 million cu.ft. Data on openhearth heats using 100% natural gas as fuel, and 20% oil, 80% gas as fuel, are shown in Table II on the opposite page.

Use of Natural Gas in Italy – After many attempts dating from remote times, and a series of unsuccessful wells that have been drilled since World War I, the first Italian well gave out natural gas at the high pressure of 170 atmospheres near Piacenza, some 40 miles southeast of Milan. Drilling operations were immediately intensified, and geological and geophysical surveys were extended to the surrounding areas.

A total of more than 50 wells have already been drilled in this area, and nearly 1000 miles of pipeline laid, conveying methane to the industrial areas throughout Lombardy. The pipeline net will soon measure 3000 miles, linking consumers in all Northern Italy to zones of production.

Gas horizons have also been established in the Marche (Central Italy) and, very recently, near Ravenna (east of Bologna); promising surveys are also reported in Sicily.

Actual production is at present 160 million cu.ft. daily; the wells now in operation have a daily capacity of four and a half times that figure. Present methane consumption by various industries is as follows:

Metallurgical	25%
Textile	15
Chemical	15
Automotive	14
Ceramics	6
Domestic	4
Others	21

Iron and Steel Foundries – Similarly to conditions in other Italian industries, elementary reorganization and repairs were the major immediate postwar problems. Wide modernization with installation of appropriate mechanical aids has occurred since 1947. Since 1949 the mean increase in productivity has been about 30% – about 525,000 tons of iron castings and 60,000 tons of plain steel castings per year.

Nodular iron is now produced in 15 of our foundries. Recent research work has indicated the possibility of using porous agglomerations of magnesium chips for the inoculant, instead of the more usual and more expensive magnesium-nickel or magnesium-copper alloys. One year's commercial experience with this modification was reported to the International Foundry Congress at Atlantic City (May 1952) by C. Longaretti and M. Noris.

Applied Research – A most outstanding occurrence in the field of research is the setting up, in 1948, of the Istituto Siderurgico "Finsider", which is engaged in carrying out the following activities for the group of steel companies in this Italian combine:

A. Selection and professional training of technicians with the purpose of improving the technical staffs of the main steelmaking companies. Selection of students is made upon the results of special psychological and technical

(Continued on p. 176)

Fig. 1 – Alcoa's New Home Office Building Nearing Completion in Pittsburgh. This 410-ft. skyscraper of lightweight construction is sheathed with aluminum panels finished with a gray anodic coating and fitted with aluminum windows

Progress in

In reviewing progress in the aluminum industry, it is interesting to look back some 50 years and see where the aluminum industry stood at the turn of the century. Substantial progress had then been made during the first decade of commercial operation of Charles Martin Hall's electrolytic process for producing aluminum. By 1900 the annual production of aluminum in the United States and Canada had risen from about 100 lb. to 5,000,000 lb.; aluminum pig, once quoted in dollars per pound, was selling for around 33¢ per lb.

Now project yourself rapidly about half a century: With the return to a peacetime economy after World War II, what had once been a search for markets became a clamor for aluminum. The industry began to speak of production in terms of tons instead of pounds. The Korean "incident" and plans for defense stimulated a new program of governmental planning. United States' production in the year 1952 has been hampered by water-power shortages but the estimates call for almost 1,000,000 tons. In 1954, the annual production should reach 1,500,000 tons. Canadian production for 1952 is estimated at about 475,000 tons and plans call for 600,000 tons in 1954.

While it appears at present that a large part of this production will be taken for defense requirements, nevertheless civilian applications will consume a substantial volume. Aside from availability and industry's increased familiarity with aluminum, the growing demand has been further stimulated by the realization that sometime in the not-too-distant future, the use of competing nonferrous metals such as copper and zinc will be restricted by increasing costs and limited reserves. Although this future of scarcity may be further off than some people have thought, nevertheless many industries are planning and working toward the time when economic considerations will dictate the use of aluminum in numerous new fields.

Plant Expansions – These large increases in aluminum production have required, of course, large blocks of power. Until recent years this demand has only been met by hydro-electric stations. The use of gas-fueled diesel engines started a decade ago, and there is now building in Rockdale, Texas, a steam-powered plant supplied with lignite fuel mined nearby. This latter development contemplates the partial carbonization of the lignite to a char which will fire the boilers, with tar being recovered as a

valuable byproduct. Some of the heavy tars may be found suitable in the production of anodes for the aluminum pots.

The industry is also looking toward Canada with its wealth of undeveloped water power. The Aluminum Co. of Canada (Aluminium, Ltd.) has under construction a large integrated operation at Kitimat, British Columbia, which will have access to the Pacific Ocean through Douglas Channel. Initially this calls for the installation of 450,000 hp. with opportunity for a future expansion up to four times this size. Alcoa has done the preliminary engineering on the Taiya project in Alaska, which calls for the eventual installation of two power houses, each with a capacity of 800,000 hp. Actual construction of the project, however, awaits authorization by both Canada and the United States.

the Aluminum Industry

By JUNIUS D. EDWARDS, Assistant Director of Research
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The growth of the industry is evidenced further by the trend toward the use of larger production units. Most of the electrolytic reduction cells now employ a current of about 50,000 amp., but there are a limited number in use which operate at loads up to about 100,000 amp. Use of the Söderberg electrode is continuing to develop, for there are certain obvious advantages in using a single, big, self-baking anode rather than many prebaked anodes in the larger cells.

IMPROVED PRODUCTS

The aluminum industry today, in view of the numerous new applications for its product, is thinking in larger terms in many directions. The aluminum smelters used to turn out their metal in the form of 50-lb. pig. Now pigs as large as 1500 lb. are being cast; they pack more economically in freight cars and in general are less costly to handle. Some mills are regularly casting 7000-lb. ingots for rolling, and ingots weighing up to 10,000 lb. have been made.

The aircraft industry is continually demanding larger sized extrusions and press forgings. Most of the construction is for the military, and the U. S. Air Force has initiated a building program for large presses to help provide the necessary parts and units for these large airplanes. These presses are of such a size that the industry could scarcely afford, at this time, to install them to meet purely civilian demand. To a large extent, therefore, these presses are being paid for by the Government, with members of the industry installing and operating them.

A large extrusion press of German construction is now being erected at Lafayette, Ind., and has a capacity of 13,200 tons. A 1500-ton stretcher for straightening the extrusions is also being installed at the same works. The program includes the building of 20,000-ton, 12,000-ton and 8000-ton extrusion presses for operation by the industry.

For the production of large forgings, an 18,000-ton press was installed at Grafton, Mass., several years ago and a 15,000-ton press is now in operation at Cleveland (Fig. 3). Two 50,000-ton, three 35,000-ton, and two 25,000-ton presses are in the blueprint and building stage.

The aircraft industry is also using tapered sheet and plate in large sizes for wing construction, and a new rolling mill especially designed for this is being installed at Davenport, Iowa.

The use of large press forgings, extrusions and tapered sheet and plate should offer aircraft builders a number of advantages for the large planes which are to be built. Ultimately there should be a reduction in cost resulting from saving time and labor. Structurally, the use of press forgings should reduce the number of parts and joints, welds, rivets, bolts, nuts and other fastenings, not only saving weight but giving smoother, streamlined surfaces with all the accompanying advantages of increased plane performance. Eventually, the availability of this equipment should lead to the wider application of aluminum for structural parts – particularly in the transportation field.

Strong Aluminum Alloys – Improved alloys have been most important in aircraft construction. There, high-strength, heat treatable alloys have their most important applications. Where extreme lightness and adequate strength were

the objective, the aluminum alloys 14S and 24S held the field during World War II. However, in 1943 a new and stronger alloy of basically different composition was introduced, named "Alcoa 75S". It contains aluminum, zinc, magnesium and copper as its chief components. Its use has gradually extended, and 75S is now being consumed in substantial amounts in aircraft construction in the form of sheet, plate, extrusions and forgings.

Even relatively small increases in strength are highly valued in aircraft design if they carry no penalty in added weight. A new material based on the Al-Zn-Mg-Cu system is now in the experimental evaluation stage. This alloy, XA78S, has about 10% greater strength than 75S, while the other mechanical properties are about the same. Although no large use of this material is anticipated at the moment, there are places in aircraft design where it should present advantages.

In the general structural field such as in land and marine transportation, alloys of lower strength which do not require such precise treatment seem to have become the acceptable standard.

Powder Metallurgy – Until recently, little use has been made of aluminum in the production of articles by powder metallurgy techniques. The late L. W. Kempf reported in 1940 that aluminum powder mixed with other metal powders such as copper, zinc and magnesium could be formed into compacts and then consolidated and alloyed by heat and pressure. Such a process, however, offered no particular advantage over well-developed die-casting procedures for making small aluminum articles of close dimensional tolerances.

A recent Swiss process, instead of making powder into finished parts, makes ingot, bar or slab stock for further processing by such techniques as forging, extrusion and rolling. As outlined in an article by J. P. Lyle, Jr., in last month's *Metal Progress*, these products have unique properties, particularly at elevated temperatures. The nonreducible oxide on aluminum powder, which was something of an obstacle in conventional powder metallurgy techniques, turns out to be a positive advantage. The films and particles of oxide in this product are not reduced at elevated temperatures nor do they form a solid solution; their presence gives stable properties and good resistance to creep at moderate temperatures.

In making this product, tiny flake-like aluminum particles are compressed and the compacts consolidated by heat and pressure. Extruded test bars having the composition of commercial aluminum (2S) have shown (Table I) interesting properties at room temperature and at 600° F. These figures for 600° F. are not changed appreciably by heating for periods at least as long as 1000 hr. Under different conditions of manufacture, products can be made with higher strengths or lower elongation, for example 23,000 psi. tensile with an elongation of 3% at a temperature of 600° F.

FABRICATION METHODS

During the postwar period, impressive progress has been made in joining methods and this has been an important factor in finding new uses for aluminum.

The development of a noncorrosive soldering flux adapted for use on automatic machinery led to the large-scale manufacture of electric light bulbs with aluminum bases. This same flux has so simplified the soldering of aluminum

Table I – Tensile Properties of (2S) Aluminum Powder-Metallurgy Products

Property	At 70° F.	At 600° F. for	
		0.5 Hr.	1000 Hr.
Tensile strength, psi.	36,000	16,000	16,000
Yield strength, psi.	24,000	14,000	14,000
Elongation	16%	15%	17%

that aluminum parts are being used in many types of apparatus and other applications where they would not formerly have been considered satisfactory.

Although insulated and covered aluminum conductors have been produced to a limited extent for many years, it was not until after World War II that this application became a large one. Today, marked economies are found in the use of aluminum wiring in buildings and factories, in secondary distribution systems, and in a large variety of special applications where electrical insulation or protective coverings are required. Special consideration must be given to a suitable, but readily available, technique in the assembly of sound and permanent electrical connections.

An increased use of aluminum in radiators and heat exchangers should follow the commercial introduction of a new type of brazing sheet. This is a clad product with a good

brazing alloy on one side of a 3S alloy core, while the other side of the core is given "alclad" protection by an alloy facing having the proper electrolytic potential.

Welding with an inert-gas shield such as argon is not a postwar development. However, its use has increased greatly in recent years. This process eliminates air and flux, with their moisture contents, from the welding area; sounder welds can be produced. Aluminum alloys containing 3 to 5% magnesium offer special advantages, because strong welds can be made having little tendency toward cracking. Both the filler wire and the plate to be welded are of similar composition and the resulting weld shows a good combination of strength and ductility without any heat treatment. The construction of welded pressure vessels and storage tanks from aluminum-magnesium alloy plate should be advanced by this development.

Large rivets of a new alloy with greater strength and improved drivability are now available for hot driving.

Plaster Molds – The introduction of torque converters in automobile transmissions stimulated the development of the plaster casting process. Molds made of plaster with controlled porosity enable the foundryman to make aluminum castings of complicated design that require only a few simple machining operations to finish them for use. The many thin blades are cast with such accurate and smooth surfaces that they need not be machined. Production of parts of this type has grown into a large business, and the process is gradually being applied to the manufacture of other cast parts where smoothness and accuracy of shape are essential.

Marine and Architectural Uses

Transportation on land, sea and air is proving to be one of the largest fields for old and new applications of aluminum. During the year, the new passenger liner S.S. United States was finished and made the fastest Atlantic crossing on record by a margin of 10 hr. The superstructure of the ship contains more than 1000 tons of aluminum; this is exclusive of minor bulkheads, furniture and fixtures. Altogether the United States contains over 2000 tons of aluminum, a substantial part of which is located topside where it is most effective in giving good cruising characteristics.

PANELS FOR BUILDING

Architecture is another field in which the use of aluminum is being extended as rapidly as the metal supply will permit. A novel idea in building construction is its use in light curtain-wall construction. The exterior of the building is faced with aluminum spandrels either wrought or cast, and then backed with a fireproof wall of lightweight concrete.

A notable example is the new 30-story Alcoa office building in the heart of Pittsburgh. This

Fig. 2 – The S.S. United States Being Outfitted at the Dock in Newport News. Much of the superstructure is aluminum

building is constructed around a structural steel frame and the exterior is completely sheathed in aluminum alloy panels which were installed complete with their aluminum windows without the aid of exterior scaffolding or derricks. These panels were stamped from sheet clad with an aluminum-silicon alloy and finished with a thick anodic coating which gives them a permanent, pleasing gray color.

This type of construction effects substantial savings in structural steel and reduces construction costs. The same type of wall may be erected with cast spandrels rather than the stamped panels, and also with sheet panels of sandwich construction. Aluminum is also finding extensive use inside buildings in decorative and functional applications.

In the picture just presented of recent advances in the aluminum industry there is every indication of continued growth in the consumption of this metal in America. This demand will be stimulated and supported by an ably conducted program of research and development by the producers of aluminum, and a large-scale expansion of smelting plants, mills and fabrication shops.

Fig. 3 — Press Forging an Aluminum Ingot With 15,000-Ton Press

By ARTHUR S. REARDON, Technical Supervisor, Heat Treat Department
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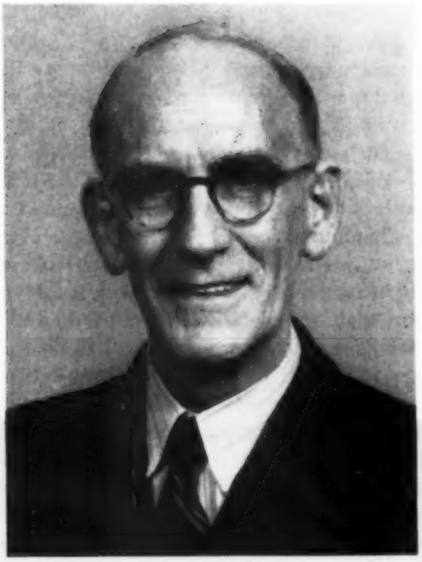


English born, Arthur S. Reardon served an apprenticeship in toolsmithing before migrating to New South Wales, Australia, in 1913. He became leading toolsmith and hardener for Clyde Engineering Co., and the first Australian member of the A.S.M. (then the American Society for Steel Treating) in 1922. He contributed an article to one of the very early issues of *Metal Progress* (June 1931) on carburized alloy rivet snaps, derived from his experience as leading heat treater with the Sydney Harbor Bridge Contract. During World War II he was forging and heat treat technician on war supplies with General Motors-Holdens-Australia, and toured the U. S. to study our practices in those fields for the Commonwealth's Ministry of Munitions.

Practical Metallurgy, "Down-Under"

Not until World War II did Australian industry become really conscious of the essential part that heat treatment plays in successful manufacturing. Production of war matériel to overseas specifications and standards was delayed at the outset by the lack of both furnace equipment and skilled men. The first was dealt with efficiently by the Ministry of Munitions and the Department of Aircraft Production. The second, even to the present time, has never been surmounted; there is still a lack of trained men with the necessary skill and intelligence to deal with the ever-widening field of heat treatment. Both opportunities for learning and reasonable inducement have been lacking, with the result that toolmakers, who in small shops had done their own hardening, and other individuals who also, in their own words, "had picked it up", were doing quite a lot of the heat treatment required.

The results were not always satisfactory, although they were usually expensive.

Of postwar trends, the following account of equipment and technique in a large and progressive commercial heat treatment shop in Australia may be indicative.

Some 20 years ago a department was established to handle the heat treat requirements of the 'C. C.' Engineering Industries, Ltd., outstanding makers of special machinery and kindred lines. A certain amount of outside work was done, but rather in the nature of an obligement for firms who had not the necessary equipment to do their own. Somewhat prior to World War II a complete unit was installed for ammonia nitriding and since it was one of two plants available for such work in the whole of the Continent, it was in continuous service throughout the war years.

Following the war considerable extension of the firm's business took place, demanding an extension of the heat treat department. Consideration was also given to the increasing necessity for what is known in the United States as commercial heat treating. Since the directors were all engineers, they realized that more equipment was not the whole answer to the problems involved but that trained men were of at least equal importance. A number of organizations were prepared to build and install any type of modern furnace but no organization was able to supply trained heat

Heat Treating in Australia

treaters. That a few such existed was known and inducements were offered to attract them to the plant.

The result was that, ultimately, four men with a good practical and theoretical background were brought together. The fact that they are all members of the American Society for Metals is an indication of their intelligence and knowledge of up-to-date overseas practice. With this group as a basis, other men were employed who, while having little experience, were amenable to training. The ASM members undertook to teach them both the practice and theory of heat treatment and to date the results have been very gratifying.

The next step was to modernize the equipment. To anticipate commercial requirements is not easy. The population of our country is still only 8,500,000 people, scattered over an area slightly smaller than the U.S.A. Obviously, our production quantities would not run into very high figures but they would be of an infinite variety. Specialized equipment was out of the question; it would never return the capital outlay. Apparently, then, it would have to be confined to that which could handle broad general lines of work, and the "impossible" jobs would have to depend upon the skill, ingenuity and capacity for improvisation of our trained men.

But first, we were convinced that the new isothermal treatments were essential if we were to handle successfully precision press tooling and similar lines. So a unit was installed embracing a neutral salt bath for austenitizing and a marquenching salt bath. Both units are gas fired with automatic temperature controls. The marquenching bath holds 1230 lb. of salt and has successfully quenched dies weighing up to 300 lb. at a temperature of 1750° F. So satisfactory was the performance and so excellent the results that a larger unit with a capacity of 2000 lb. of salt was installed within the next six months.

A very considerable tonnage of work has now passed through this equipment. Austem-

Fig. 1 – Group of Baths for Isothermal Heat Treatments at 'C. C.' Engineering Industries, Ltd., Sydney, N.S.W., Australia

pering has included such things as chain saw teeth, paint scrapers, screwdrivers, putty knives, skate blades, multigrip pliers, springs and similar mechanical parts. Martempering has covered the whole of our precision tooling with the exception of the hot die and high speed tools. Steels treated have included the carbon-manganese, high-carbon-chromium, martensitic stainless, and chromium-tungsten, involving a temperature range from 1435 to 1870° F., and with results that would often have been otherwise impossible.

Since we have no gear quenching presses, we were quick to realize the possibilities of marquenching for gears. Now it is standard practice with us to quench all gears in this way, including the case hardened nickel-chromium types as well as the straight hardening nickel-chromium and the nickel-chromium-molybdenum grades. The results have always been within the limits of tolerance required. Our eternal thanks are due to Messrs. Bain and Davenport who pioneered this greatest advance in heat treatment practice in our time, and to other members of the American Society for Metals like Messrs. Widrig and Groves who put the idea into commercial practice and told about their successes for others to emulate.*

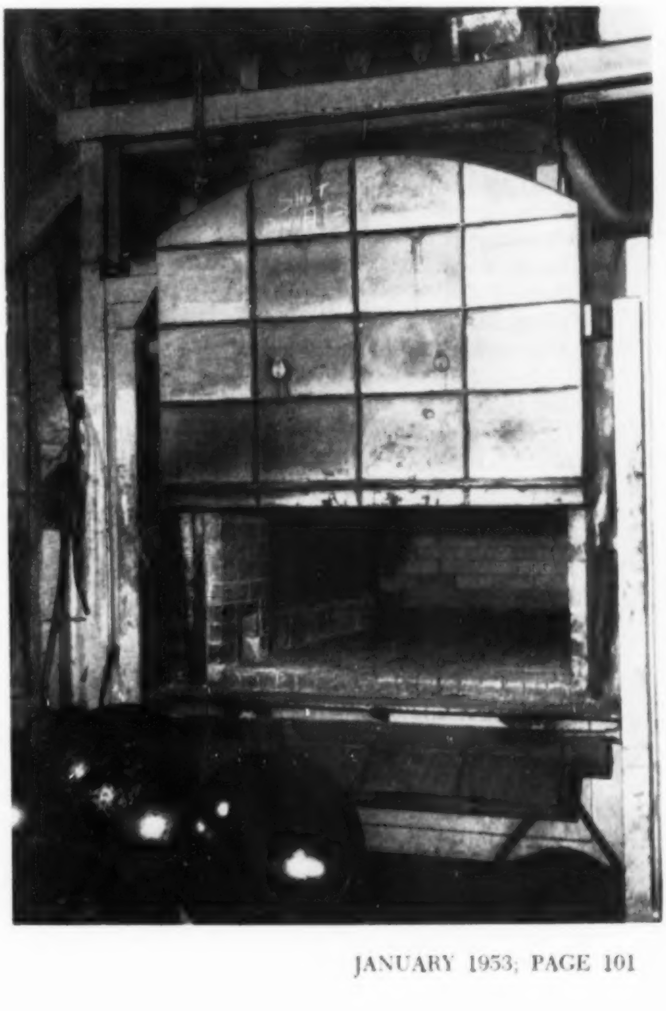
The limiting sizes of our batch-type furnaces were forcing us to turn away a considerable amount of work by this time, and so finally a new unit was installed with a working length of 7½ ft., width of 5½ ft., and height of 30 in. With this furnace (Fig. 2) we have been enabled to pack carburize and harden plastic molds weighing 1120 lb. and shear blades and similar work to a length of 7½ ft. Volume of work on shear blades has steadily grown and our technique has developed to a point where we can produce them so that an allowance of 0.030 in. is sufficient to grind up all surfaces. The materials involved have ranged from water quenched straight carbon steel to tungsten hot die and high speed steel. Herein, the ancient cunning of the old-timers, as apart from information from the textbooks, has been of value.

This same equipment has handled a considerable tonnage of stainless and manganese castings at the higher temperatures, as well as stress-relieving of welded structures and iron castings in the lower ranges.

The growth of the die casting industry from infancy to maturity has been very rapid and the tooling involved has made, possibly, the heaviest demands upon the skill of our team. Steels used range from the nickel-chromium-molybdenum types, treated before machining,

*A.S.M. publications have been indispensable to us. I recall gratefully that an article on springs in one of the early issues of *Metal Progress*, fortunately saved, showed the way to improve firing-pin springs in field guns and prevent calamitous failures in use. A much more recent instance is "Martempering of Automotive Gears and Shafts" by S. L. Widrig and Wilson T. Groves of Spicer Mfg. Div. of Dana Corp., Toledo, Ohio, in *Metal Progress* for May 1950.

Fig. 2 – Batch-Type Furnace Showing Shear Blades on Hearth. Technique is sufficiently precise that an allowance of only 0.030 in. is required for grinding. Rough disks in the foreground are ready for treatment



to the hot die types for brass die castings. Martensitic stainless steels have become increasingly popular, and since many of the dies are too large to heat in our liquid heat units, methods have had to be devised to treat them in batch furnaces without controlled atmospheres. Finished dies must have not only the required hardness but high precision and scale-free surfaces and – in the case of the hot die steels – no case either hard or soft. Success in producing these dies we count as one of our best achievements.

Until recently the demand for high speed steel treatment has not been great. Open furnaces were the rule. Here again, however, the demand has grown to a point where salt baths became essential. Three electric units have now been installed – preheat, high temperature, and quench – and not only have the standard treatments been carried out but experimental work has been done on the bainitic treatment. The latter has given surprising and generally successful results.

From many parts of the world have come the metals we have treated: brass and steel sheet from Japan, constructional and toolsteels from England, Germany, Yugoslavia, Canada and (too rarely) the U.S.A. All of them are excellent but vary in many ways in their response to treatment. Our own local steel mills are also doing a fine job and turn out a complete range of materials from the low carbons right through the complete series of constructional alloys and all grades of spring and toolsteels. This also is true of our steel foundries with a high production of Hadfield's manganese steel and several grades of stainless. In the field of nonferrous products those of the Aluminium Co. of Australia have long been recognized as of world standard.

WHAT OF TOMORROW?

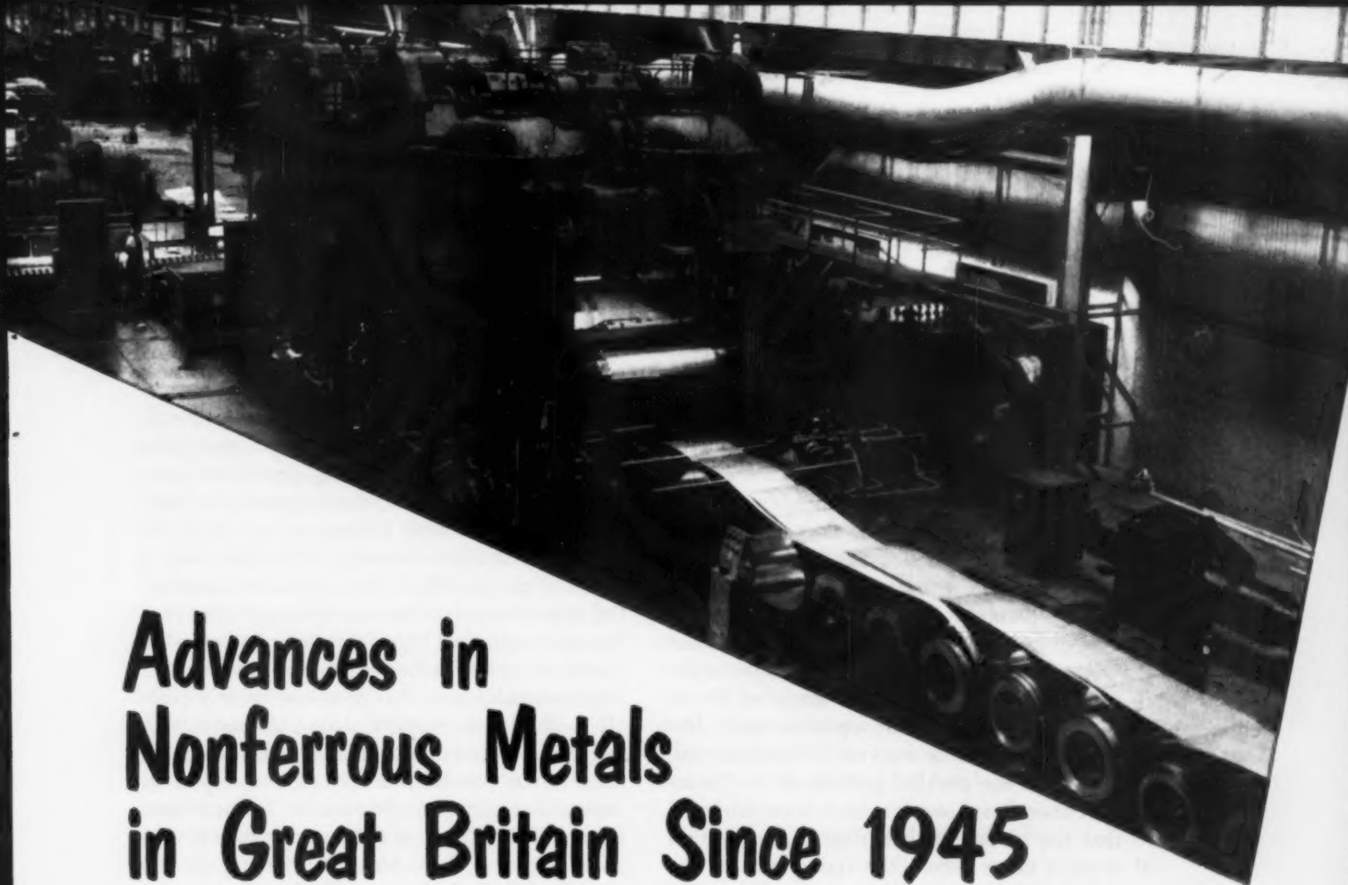
The future for metallurgy in Australia is particularly bright – indeed, almost excitingly so. The discovery of uranium deposits of very great promise, together with new copper and silver-lead districts, may quite well overshadow the gold rushes of the past. The search for oil continues with much optimism. In addition, the Snowy River hydro-electric scheme now being developed will give an impulse to our metallurgical developments greater than we have yet known.

In my own more restricted sphere of heat treatment we shall be ready to take full advantage of this development. As the occasion warrants we shall install more and more modern equipment. We already have under consideration atmosphere-controlled furnaces, as well as equipment for carbo-nitriding and gas carburizing. In the past three years we have trebled our equipment and we are hopeful that the next three years will see equal or even greater progress.

In all this concern with equipment we are not unmindful of a statement by one of the old-timers: "The best heat treatment is still being done by the best heat treaters." We endeavor to keep abreast of overseas practice and are at all times ready to experiment. In our efforts to produce good heat treaters we are encouraged by a statement of the late W. H. Hatfield in *Transactions* of A.S.S.T. as long ago as May 1929. In the third Campbell Memorial Lecture on "Application of Science to the Steel Industry", Dr. Hatfield said:

"For many centuries swords, knives and the like have been hardened and tempered and the finely tempered sword, an article in past ages much in demand, was produced long before pyrometric observations and the science of metallography had explained the fundamental principles of such processes. In considering the hardening and tempering of steel parts for airplane and automobile work, we are only following the example of the time-worn procedure of the old cutlers and armorers. Now be it noted that a novice would never, in the old days, have been permitted to harden and temper, only the highest skill and experience permitting the production of the desired results – and today the same remarks apply. There is quite enough scope in the art of hardening and tempering small and large parts, such as used in the various branches of engineering, to justify the growth of a class of operators with brains to understand and skill to execute the treatments required to obtain those excellent qualities which skillful hardening and tempering will induce. Bearing on this, it not infrequently happens that small parts are required in which one portion will have to be finely tempered and tough, whilst the other is quite hard, and even more difficult requirements can be met, providing the development of the necessary technique in the operator is insisted upon. In the whole range of steel metallurgy there is no direction where careful study and good technique can produce more valuable results."

I wish to emphasize the last sentence.



Advances in Nonferrous Metals in Great Britain Since 1945

IT IS THE ingrained and unfortunate habit of the British people to take an unnecessarily modest view of their country's scientific and technical achievements but it is hoped that this brief review of the more outstanding developments of our nonferrous metals industry during the past decade will serve to refute the oft-repeated assertion that British industry is slow in putting the results of fundamental scientific research into practice.

In any such appraisal it has to be remembered that the economic situation and the diverse character of our markets demand that the emphasis shall be on quality production of a large variety, rather than on the quantity production of a smaller number of products – although Britain has not, in truth, been backward in installing equipment for mass production where the necessity arises.

Aluminum Mills – It is in the light alloy field that, during the past few years, most spectacular advances have taken place. As examples may be cited the Falkirk Works of the British Aluminium Co. Ltd., and the Rogerstone Works of the Northern Aluminium Co. Ltd.

At the former works, for instance, completely modern equipment produces aluminum sheet up to 6 ft. wide, heat treated strip in coil form, and sheet and plate to specially close tolerances and with a very high degree of flatness. At Rogerstone, flat sheet to a width of 56 in. and corrugated sheet 32 in. wide, both in a maximum length of 20 ft., are fabricated in one of the most up-to-date continuous mills in the world. Container sheet, 36 x 30 in. with a thickness of 0.008 to 0.018 in., and foil stock in coils up to 2000 lb. in weight, are also produced. The photograph at the top of the page shows the entrance side of the three-stand cold mill at the Rogerstone Works, with end-sheared coils from the hot line awaiting cold rolling. Present total output is in the neighborhood of 50,000 tons of sheet and strip a year, the total output per man having increased fivefold. With the addition of cold rolling equipment a total yearly output of 150,000 tons is planned.

In rolling practice, generally, the introduction of hydraulic variable-speed drives to strip

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mills has resulted in more accurate control of tension in strip during rolling and coiling.

Floating Plugs for Tube Drawing – One noteworthy achievement in the tube industry is the development of the floating plug method of tube drawing, its chief advantage being that it enables tubes of any length to be produced, the only limitation being the size of the original billet. A number of British manufacturers have adopted this method, to the virtual exclusion of both mandrels and anchored plugs.

In brief, the success of the floating plug depends on its ability to stabilize itself in the die orifice, and to assist materially in the gage reduction. The controlling size of the plug is the parallel portion, or "bearing", A of Fig. 1, but leading to this there is a length of straight taper, B, usually giving an inclusive angle of 6½ to 8½°. A number of users operate with dies where the lead-in is curved or bell-shaped, merging into the parallel portion of the "bearing". Other dies, however, have been designed so that the leading-in bell runs into a portion of straight taper before the sizing part of the die is reached. In general, the taper of the plug is 1 to 2° less than the entrance taper in the die, thus creating a slight wedge effect.

With the introduction of the push-pointing, automatic tube bench designed so that one, two, or three tubes can be drawn simultaneously, drawing speeds up to 100 ft. per min. are also obtainable. With copper tubes an average of 35% reduction in cross-sectional area is obtained on each draft. Operation can be entirely automatic or the machine worked by sections, the whole series of operations being controlled from one desk.

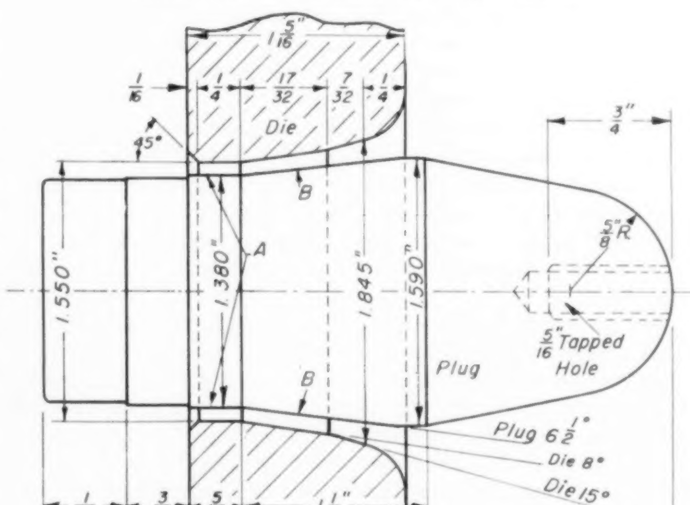
Extrusions – The scope of light alloy extrusions has been greatly increased by the use of a bridge mandrel. A plate containing four holes is placed between the die orifice and the billet, separated by a spacer ring. A short mandrel (2 to 4 in. long) extends from the back plate to the die orifice. The advantages of this arrangement are that the die orifice need not be circular nor the mandrel central; thus, tubes with flanges and double tubes can be produced and, within limits, can be extruded to finished dimensions.

In the development of new alloys Great Britain has always played an important part. Interesting news in this field is that the old method of hit-and-miss is gradually giving way to the more scientific approach in that many of the new alloys, particularly light alloys, are based on the fundamental work in metal physics carried out by Dr. Hume-Rothery and his school.

NEW ALLOYS TO WORK AT HIGH TEMPERATURE

Magnesium – In the foundry field ternary alloys of magnesium with zinc and zirconium have been developed having proof stresses nearly double those of the magnesium-aluminum-zinc series, with fatigue values of 12,500 psi. for 50 million reversals of Wöhler fatigue tests. Wrought Mg-Zn-Zr alloys show substantial improvement in mechanical properties over Mg-Al-Zn-Mn and Mg-Mn series. In both, the zirconium eliminates the tendency toward stress-corrosion and also gives a more workable alloy. Still better properties are obtainable with magnesium-zirconium-zinc alloys containing 3% cerium mischmetal; certain of these possess outstanding creep resistance at temperatures up to 480° F., freedom from microporosity and good foundry characteristics. Owing to the fact that Mg-Zr-Zn has practically zero creep at 400° F., this has become the standard material for jet engine parts. The newest comer in this field is Mg-Zr-Zn plus 3% thorium, trade named "Elektron ZT-1". The improved creep resist-

Fig. 1 – Dimensioned Sketch of Floating Plug and Die to Reduce Copper Tube From 1.845 In. O.D. x 0.110-In. Gage (16%) to 1.550 In. O.D. x 0.085-In. Gage (23%)



ance of this alloy makes it suitable for castings which are expected to withstand temperatures in the range of 480 to 660° F. It is easily founded, is free from microporosity and possesses the same resistance to corrosion as do the same alloys with cerium (mischmetal) additions. A simple stabilizing anneal at maximum service temperature is the only heat treatment necessary for the casting.

Aluminum – In aluminum alloys the latest development is an alloy containing 4.5% copper, 0.6% manganese and 0.1% cadmium. It is produced as extrusions, forgings and sheet. The alloy possesses good workability and can be hot rolled with negligible edge cracking.

Turbine Blades (Nickel Alloys) – In solving the high-temperature problems presented to the metallurgist by the gas turbine engineer, Great Britain has always been well to the fore. The Nimonic series of alloys (age hardenable, high in nickel, low in chromium) is a case in point, with Nimonic 75 for combustion chamber components and Nimonic 80 for aircraft rotor blades. Two of the latest in this series are Nimonic 90 and Nimonic 95. The latter, developed from Nimonic 90, is stronger and stiffer but can still be hot worked and machined. When used for the rotor blades of gas turbines, its operating temperatures are 90° F. above those at which Nimonic 90 is employed.

Copper Alloys – In the condenser tubes of marine vessels the aluminum brass devised by the British Nonferrous Metals Research Association, with 76% copper, 22% zinc, 2% aluminum to which is added 0.02% arsenic for resistance to dezincification, has given outstanding service. The need for a free-cutting, high-conductivity copper rod with a conductivity of 98% of International Standard has warranted the development of an alloy containing 0.55 to 0.65% tellurium, balance copper. In the same field, an age hardenable alloy with the nominal composition of 0.2% phosphorus, 0.2% sulphur, 1.0% nickel, and the remainder high-conductivity copper, with an electrical conductivity (when tempered) of 60%, offers the combination of reasonably good conductivity with strength approaching gun metal, free machinability of brass, facility to harden other than by cold work after fabrication, and the maintenance of hardness and strength at elevated temperatures – truly a remarkable combination of advantages. Both these high-copper alloys are eminently suitable for such items as switch parts, bolts and studs, electrical connectors, commutators, contacts and welding and cutting nozzles.

A slightly modified Britannia metal is capable of considerable hardening by simple heat treatment and has an improved "ring", thus making an ideal alloy for hotel hollow-ware.

FOUNDRY TECHNIQUES

In nonferrous founding, one of the most important British achievements has been the flux degassing process which enables tin bronzes and phosphor bronze to be produced successfully from ordinary grades of metal or from scrap, where previously high-grade metal was essential. The flux contains borax, sand and copper oxide. Using this method, phosphor bronze with 10% tin gave 54,000 to 62,500 psi. tensile strength and 10 to 20% elongation on 2 in., and a 10% tin bronze extruded and cold rolled gave 165,000 psi. tensile. "Blowing" in an ingot – even with very unfavorable mold and pouring conditions – is eliminated by dressing the mold with a thin coating of resinous aluminum paint.

In die casting of aluminum alloys, outstanding results have been obtained by using bottom-fed dies and air pressures so low that the speed of filling is roughly comparable to that of a permanent mold.

Fig. 2 – Six Stages in Drawing a Jet Engine Component From Stainless Steel Sheet. Centrifugal-cast aluminum bronze dies prevent scoring and other surface damage to such materials of high elastic limit

DEEP DRAWING DIES

Deep drawing of material of high creep strength such as Nimonic, Inconel and austenitic steels to produce scratch-free press-

ings is not simple because of the tendency of these metals to pick up, scuff, drag or gall when conventional steel dies are employed. Use of centrifugally cast aluminum bronze dies, which is the practice of many British fabricators, does much to obviate this (Fig. 2). Aluminum bronze offers adequate resistance to deformation, possesses sufficient initial hardness, and is capable of work hardening. Furthermore, aluminum bronze takes and maintains a high polish, and has a natural slipperiness which is said to contribute much to its success in drawing these difficult metals.

Fig. 4 — Tableware Plated With 65-35 Tin-Nickel Alloy Requires No Cleaning! It is the only known base metal alloy which is unaffected by salt. (Courtesy Tin Research Institute)

JOINING AND WELDING

In the joining of metals, the twin holder technique developed by the British welding Research Assoc. for metal-arc welding of heavy aluminum alloy sections, has done much to increase the application of aluminum alloys. Welding speed for ½-in. plate can be doubled.

Cold Welding (or pressure welding), by which ductile metals can be welded by pressure alone, is increasing in number of applications. With a suitable arrangement of workpieces and dies, application of pressure brings the faying surfaces into close contact while plastic flow is taking place, so that they become solidly joined together. Cleanliness of the surfaces is of paramount importance; pressure must be applied over a comparatively narrow strip, with considerable displacement of metal.

The process is used in the fabrication of light steel sections, for light alloy sheet, in the production of Alclad, in bridge die extrusion of aluminum and lead (mentioned earlier in this article), and to a lesser extent in joining precious metals. Recent applications are the sealing of aluminum containers for electronic tubes — the welds are airtight and the containers are suitable for use in any climatic conditions. Aluminum-sheathed cables made by this process are lighter and mechanically stronger than their lead-sheathed counterparts.

Fig. 3 — Ultrasonic Vibration Breaks Oxide Film on Parts to be Soldered, Expedites Tinning, and Improves Bond. (Courtesy Mullard, Ltd.)

Soldering by ultrasonics, using either a soldering iron or immersion bath, is also being widely adopted. The ultrasonic soldering bath, in which the articles are tinned simply by immersion into molten solder agitated at 20 kilocycles per sec., offers an ideal method for the rapid tinning of small complex-shaped aluminum articles. Agitation breaks up the oxide film and eliminates the use of fluxes. Soft tin-lead solders may be employed but there are certain advantages in using tin-zinc. For work on aluminum, the greater ease and speed of working and the more efficient coverage result in greater joint strength and corrosion resistance. The method is easily adapted to continuous production processes.

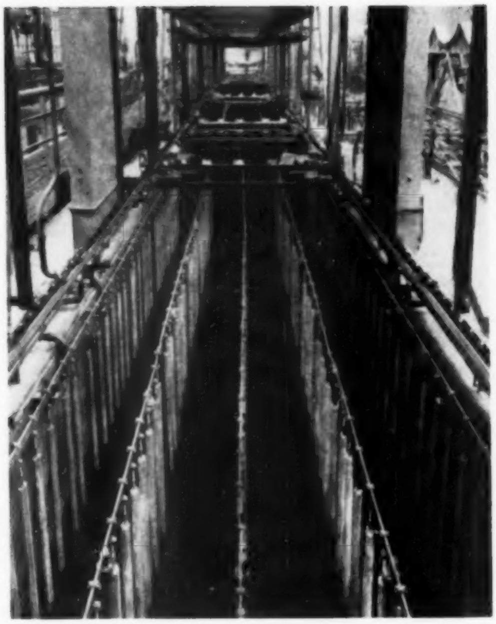


Fig. 5 – View Along the Electrogalvanizing Tank for Plating Metal Window Frames, Showing Arrangement of Zinc Anodes. (Courtesy Electrochemical Engineering Co., Ltd.)

The ultrasonic soldering iron shown in Fig. 3 is particularly suitable for the surface treatment of faulty light-alloy castings and for the repair of aluminum patterns. A strong bond is obtained between solder and base metal. The tin-zinc solder used has a texture and color similar to aluminum and, after machining, treated areas are indistinguishable from the surrounding parts of the casting.

ADVANCES IN METAL FINISHING

Outstanding improvements have been made in the speculum and tin-nickel plating processes. In speculum plating, an alloy of copper with tin between 39 and 55% can be plated on all the common metals. The coating, which has a silver-like color, a coefficient of reflectivity approaching that of silver, and can be readily polished to a high luster, is hard and does not tarnish in indoor atmospheres. Since it is also unattacked by food products, it is eminently suitable for tableware and hollow-ware. It has also been plated commercially on mild steel vacuum tubes and zinc-base die castings. However, it is not recommended for outside exposure except when fully protected – as, for example, the inside reflectors for automobile head lamps.

Metal Spraying at 10 Ft. per Min.

Fully bright coatings, with remarkable resistance to tarnish and corrosion, are obtainable by plating with 65-35 tin-nickel alloy. On nonferrous metals the coating is relatively porefree at a thickness of 0.0005 in.

Researches on galvanizing by the British Nonferrous Metals Research Assoc. resulted in the development of an improved process in which a given weight of zinc can be used to coat a substantially increased area of steel without detriment to the quality of the galvanized wire, without important changes in plant, and without lowering production rates.

Indicative of the capabilities of British manufacturers in the metal finishing field is a continuous electrogalvanizing and painting plant for metal windows which came into operation in 1951. This unit, the largest in the world (shown in Fig. 5), is 305 ft. long and 12 ft. wide, and has an output of 2500 finished frames (10 x 5 ft.) per week.

In a similar category is the first automatic metal-spraying equipment, for the spraying with aluminum of the structural steelwork erected above crane level at the new works of the Steel Co. of Wales. In this unit, 12 x 5-in. rolled steel sections are coated with a minimum of 0.004 in. of aluminum at a speed of 10 ft. per min. using banks of wire pistols which total 18 nozzles; 28 nozzles can be accommodated. It is intended to make this device completely automatic by the installation of electronic controls. (A similar British device for metallizing tubes was described in *Metal Progress* for November 1952.)

Minor but none the less important advances can also be recorded.

First, a process for recovering germanium – used extensively as a crystal rectifier – and gallium from flue dusts has made this country independent of supplies from abroad.

Second is a method of coating glass with a thin, transparent film of tin which will conduct electricity. Visibility is reduced by a negligible amount and an electric current can be passed through the coating to keep it free from icing or misting. In practice, the coated glass is sandwiched between two layers of ordinary glass and offers distinct possibilities for windshields and for shop windows to keep them from steaming over in cold weather.

Pioneer in the construction of prefabricated aluminum bungalows – an immediate postwar project which helped the serious housing shortage – Great Britain has made notable strides

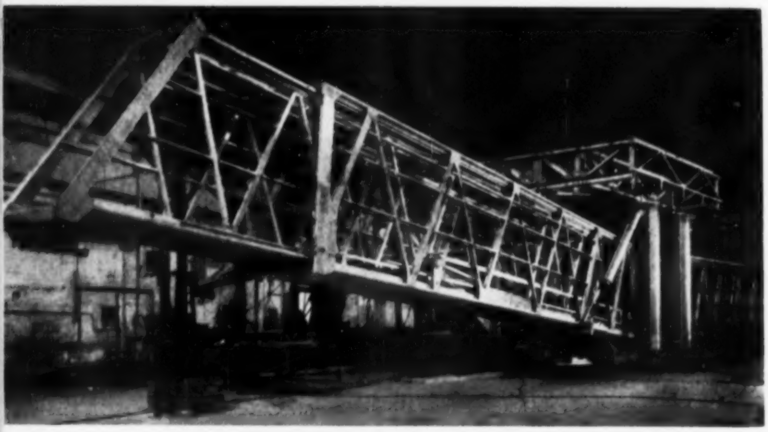


Fig. 6 – Telescopic Gangway and Inshore Extension (Before Covering With Aluminum Sheathing), All-Aluminum, Made by Structural and Mechanical Development Engineers, Ltd., for the Ocean Terminal at Southampton

in the use of aluminum in building and structural engineering. Some important structures are all-aluminum. In all, about 260,000 tons of aluminum have been so used in the past five years, which is about one quarter of the total output of fabricated aluminum.

ALUMINUM BUILDINGS AND BRIDGES

Many American travelers are acquainted with the telescopic gangway for the Ocean Terminal at Southampton, a structure which is remarkable for the economy of its structural design (Fig. 6). Using aluminum, the load on the shore structure is minimized and the size of the operating mechanism reduced. Another instance where aluminum alone could have made the project feasible is the door for the hangar which houses the huge Brabazon aircraft. This door, of aluminum alloy, 65 ft. 9 in. high and 1045 ft. long, can be opened completely in 2 min.

At London Airport an all-aluminum hangar with a clear span of 125 ft., a length of 110 ft., clear door height of 30 ft., each bay of which has an over-all span width of 150 ft., was constructed in 1951. The total weight of the complete building is 312 tons – the skeleton accounting for 95 tons and sheathing 100 tons. Owing to the light weight of the aluminum alloy, a unique method of erection was used. Legs and half-arches were erected flat on the ground. Legs ended in huge pins, and matching halves were placed on their proper pedestals and the arches raised into position and joined at the center in a very short time.

In 1948, the first aluminum bascule bridge in the world (90-ft. span, using 51 tons of aluminum alloys) was opened at Sunderland.

Featured at the Festival of Britain in 1951, the Dome of Discovery, with an over-all diameter of 365 ft., a height to the center of 90 ft. and a circumference of over one fifth of a mile, was built entirely in aluminum alloy.

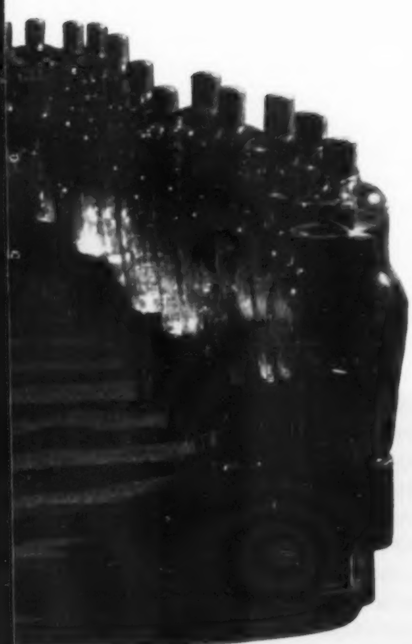
In the marine field, too, aluminum is making considerable progress. In 1947, Lloyds Register of Shipping issued its trail-blazing "Tentative Requirements for Quality and Testing of Aluminium Alloys for Shipbuilding Purposes". A standard for shipbuilding plate (N.P. 5/6) has now been adopted in this country. Containing about 4% magnesium and a certain amount of manganese, this alloy when hot rolled meets Lloyd's requirements with a handsome margin. It should be noted that this material attains its mechanical properties without heat treatment – a factor of considerable importance in use. Should a fire occur aboard ship, no loss in strength of the material at high temperature is to be anticipated.

Apart from the superstructures of large craft, a number of smaller vessels have been built entirely of aluminum employing the familiar methods of aircraft construction. In brief, the shell of the boat is prefabricated in a flat, unstressed condition so that it can be flexed about the center line into the shape of a complete boat having a rigid structure, and conforming accurately to the designed curves of waterlines and sections. By this method of "two-way tension", the weight of the hull can be reduced by as much as 60%.

Employing pre-extruded aluminum tube into which the cable case is threaded, and following with swaging and sinking operations, seamless aluminum-sheathed cables are being manufactured in considerable quantities. Up to date, 2100 miles of aluminum-sheathed cable has been produced by one British firm alone using this method.

CONCLUSION

This necessarily brief series of notes on a number of matters of more than casual interest should indicate to our metallurgical brethren throughout the free world that British ingenuity is still at work and is producing materials and methods which are substantially better than yesterday's best.



Metallurgical Research in the Netherlands

By J. D. FAST, Chief Metallurgist, Research Laboratories, and E. M. H. LIPS, Chief Engineer Metallurgical Development Laboratory, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Netherlands

THIS SURVEY will be confined to research on metal fabrication techniques and on the utility of metals and alloys, primarily as conducted at two of the best known centers in our country, the Technical University at Delft and Philips' lamp works at Eindhoven. It would be amiss, however, to refrain from mentioning – even if only in passing – the fundamental studies of metallic conductivity of heat and electricity at the Kamerlingh Onnes Laboratory of the University of Leiden. Further, in the interest of brevity, literature citations will be omitted in the following paragraphs.

SHEET AND PLATE

Dies for Deep Drawing – In studying the deep drawing properties of sheet metal, we concluded that the suitability for drawing *with a given tool* could be predicted from the true stress-strain diagram of the material. (Derived from the latter are the yield point, the strain hardening factor and the strain in the necked region.) However, the determination of these values was quite difficult in very thin test pieces – 1 mm. or less.

An important result of this study is an improved die profile which is shaped according to a well-known mathematical curve, the so-called tractrix. In such a die, the deep drawing limit can be increased up to 58%.

Blanking Operations – Tool life is often an important factor in the price of sheet metal products. It was observed in Eindhoven that transformer steel and phosphor bronze sheet from different suppliers, meeting the same specifications, varied considerably in the number of blankings per tool-grind.

Systematic research showed that given proper annealing, such differences are due to the content in hard inclusions (oxides of silicon, tin and aluminum). A direct relationship appeared to exist. Taking advantage of this result, a Netherlands steelworks succeeded in producing dynamo steel with exceptionally good shearing properties.

Drawability – The tensile and hardness tests, the alternating bending test, the cupping test, the normal impact tests, and the special Schmadt impact test were critically analyzed by J. H. Palm in the National Aeronautical Research Institute at Amsterdam. Consideration of the stresses and strains in the elastic as well as in the plastic range gives a better understanding of the meaning of these tests. Dr. Palm renews a plea for making more use of the reduction of area figure obtained in the normal tensile test, and arrives at the following conclusions: *(a)* In determining the quality of sheet metal, the alternating bending test is at least as useful

as the normal cupping test; *(b)* the Schnadt impact test has no particular advantages over the normal impact tests.

Brittle Steel Plate – A mechanical test for the tendency toward brittle fracture of mild steel plates was developed in Ymuiden by J. H. van der Veen. The principal features of this slow bend test, resembling Bagsar's "DX-test", are that the specimen includes the full thickness of the plate and that fracture starting from a sharp notch is made to propagate in a direction parallel to the surfaces of the plate. These features were chosen in order to obtain similarity to stress conditions met in practice.

PERMANENT MAGNETS

Before the Second World War, research in the domain of magnetism led to the improvement of permanent magnets having highest flux density. It was discovered by Messrs. Holst, Jonas and van Embden in Eindhoven that the product $(BH)_{max}$ of certain magnetic alloys could reach a value never attained before by proper heat treatment in a magnetic field. This material is called "Ticonal" (the American name is "Alnico V"), and it is now being widely used.

Another new permanent magnetic material called "Ferroxdure" was discovered by J. J. Went and his associates in the Philips' Laboratories after the war. In it all metals are replaced by metal oxides, a prototype having the composition $BaO \cdot 6Fe_2O_3$. An important feature is that they do not contain any nickel or cobalt – strategic metals contained in most other magnetically hard materials. Ferroxdure is characterized by an extremely high value for coercive force, due to a large crystal anisotropy, and by rather low remanence and saturation magnetization, and is very useful in many applications where a high resistance to demagnetization is of importance.

Rathenau and his co-workers found that Ferroxdure can also be considerably improved by applying a strong magnetic field before and during compacting of the oxide powder.

GASES AND METALS

In Eindhoven much work has been done on the interaction between gases and metals. In addition to fundamental studies of gas adsorbed or dissolved in many of the less common metals, including titanium, and of the permeability of metal walls to gases, the work has been extended to investigate the causes of porosity in welds and castings, the influence of oxygen and hydrogen in arc welding, the hardening of metals by internal oxidation, the influence of molybdenum oxide on the rate of oxidation of metals, the embrittling effect of oxygen on iron, and the role of nitrogen in steel. Some of these latter items, of more immediate interest to metals engineers, will now be mentioned briefly.

Hardening by Internal Oxidation – It is well known that the two commercial methods of increasing the hardness of alloys, martensitization and precipitation hardening, are fundamentally based on the power to regroup the atoms in the metallic crystals. J. L. Meijering and M. J. Druyvesteyn have discovered a new method and principle – hardening by internal oxidation, based on the formation of oxide molecules in the interior of the metal when oxygen is allowed to diffuse inward. If, for instance, silver containing 0.3% magnesium is heated in air at 1475° F., its hardness increases from 35 to 175 Vickers; submicroscopic MgO forms in the metal lattice. No substantial hardening results if the oxide gets the opportunity to coalesce into coarser particles.

It has been found that such coalescence will occur if the difference in affinity for oxygen between the solute and solvent metals is not very great. This means that only metals with a relatively small affinity for oxygen can be hardened by internal oxidation; such metals are silver, copper and nickel. The mechanical properties of the metals so hardened do not change at high temperatures. Recrystallization and creep are slowed down considerably. A drawback is the intercrystalline brittleness which arises when the hardness is rather high.

Influence on Scaling Rate – Resistance against oxidation of many important metals is due to a protective oxide layer. It was found by G. W. Rathenau and J. L. Meijering at Eindhoven that the protection is lost as soon as a liquid phase is formed in the oxide. This means that oxides with low melting points can destroy the protective action – especially since their melting points are often considerably lowered by mixing with the more refractory oxides of the original protective layer. For instance, the scaling rate of copper rises abruptly at 1000° F. if MoO_3 is present; thermal analysis of MoO_3-Cu_2O mixtures yielded a eutectic arrest at this temperature.

Accelerated oxidation may also occur in the absence of a liquid phase – namely, when substantial amounts of molybdenum oxide are in-

corporated into the scale. (Such a complex oxide phase was found on a 25% chromium steel.) An interesting example is the oxidation of silver. Above about 350° F. this metal cannot oxidize in air, the dissociation pressure of Ag_2O being greater than the partial pressure of oxygen in the air. MoO_3, however, stabilizes the oxide Ag_2O by the formation of the molybdate Ag_2MoO_4, but this oxidation is again accelerated by the formation of a liquid phase above 900° F.

Embrittlement of Iron by Oxygen – In an investigation on the impact strength of *pure* iron and pure iron with purposely added impurities, it was found by one of us that on the order of 0.01% oxygen has an embrittling effect – the transition from ductile to brittle behavior is shifted to higher temperatures. Oxygen causes the brittle fracture to run partly along the grain boundaries; in other words, oxygen promotes intergranular brittleness. In the case under consideration, the fracture strength of the grain boundaries is much smaller than that of the interior of the grains and it seems reasonable to assume that fracture starts in the regions where the reduction of the fracture strength is localized – that is, at the grain boundaries.

In other experiments where 0.02% carbon was added to pure iron, it appeared that carbon, even if present at the grain boundaries, has a very small effect upon the impact behavior. This great difference in effect between oxygen and carbon could be explained by assuming the oxide to be present along the grain boundaries as a continuous skin (perhaps only a few molecules thick), while the carbide could be said to form separate little islands along the grain boundaries.

A most remarkable effect was found when experimenting with iron containing both oxygen and carbon as impurities. It appeared that a few thousandths per cent of carbon suffices to reduce considerably the detrimental effect of a much greater content (a few hundredths per cent) of oxygen. It is assumed that traces of carbon change the interfacial tensions in such a way that the iron oxide at the grain boundaries coalesces into separate particles, thereby destroying the continuous oxide skin that was supposed to exist.

Aging, we believe, is mainly caused by nitrogen in soft steel, and to a much lesser degree by carbon – as is true also of "blue brittleness".

Oxygen (in contradistinction to carbon and nitrogen) causes virtually no age hardening in soft steel. This indicates that the solubility of oxygen in alpha iron is very much smaller than that of carbon and nitrogen, unless one assumes that oxygen atoms replace part of the iron atoms in the lattice whereas carbon and nitrogen are interstitially dissolved.

Experiments have also revealed that up to 0.5% Mn does not influence the rate of formation of carbides, but enormously retards the precipitation of nitrogen. These facts were discovered when studying the "magnetic aging" of steel, now ascribed to the combined effect of nitrogen and manganese, and not (as was formerly assumed) to nitrogen alone.

WELDING RESEARCH

In the domain of arc welding much research and development work is done in the Netherlands. This work, described in many articles in the *Philips Technical Review*, leads to several interesting results, of which we can here mention only a most important one – the development of a new type of welding rod, the so-called "contact" electrode.

A disadvantage of the older types of electrodes is that the welder must maintain a definite arc length. If the arc becomes too long, the weld has an irregular appearance and insufficient penetration, and there is much loss from spattering. Time is also wasted when the arc is drawn out and broken inadvertently. If the arc length is too short, the electrode freezes to the workpiece. Particularly with heavy-gage rods it is very difficult to maintain the correct arc length.

In the contact electrodes this objection has been overcome by incorporating a large part of the iron as a powder in the coating, which as a consequence is of such thickness and strength as to permit "touch welding". The electrical conductivity of this coating, impregnated as it is with iron powder, makes the contact electrodes self-starting and nonextinguishing. The penetration of the welds so made is remarkably good.

Self-Starting Welding Electrode

Metal Industry In Japan

Prepared by the Ministry of International Trade and Industry, Japanese Government

Before the war, Japan was, in its several branches of metal industry, among the best ten in the world. In 1946, the first year after the war, however, due to the loss of such territories as Korea and Formosa, and to lack of raw materials formerly received from China and Southeast Asia, the metal industry produced less than one tenth of its 1940 output, while the total output of the mining industry decreased 67% during the same period. Lack of raw materials caused changes in the processes of concentration and smelting, and war damage delayed recovery of domestic raw materials. However, the Occupation's policy and the efforts of the Japanese people brought about a gradual increase in production.

Restoration of the normal diplomatic relations with the free world has improved the importation of raw materials, and metal production has increased almost up to the prewar record. However, there are still many problems to be solved in connection with the changing situation of material supply and the modernization of plant and apparatus that were devastated during the war.

Sharp fluctuations have been witnessed in the last ten years in the iron and steel industry (Fig. 1). The highest level of production at the outbreak of World War II was followed by stagnation immediately after the war's end. This industry, being on the road to recovery by 1948, saw a marked advance of production in 1950 after the outbreak of the Korean war; and yet, in 1952, when a new balance of supply and demand of iron and steel was attained in the world market, the domestic market also became stagnant.

Iron and Steel Production – As shown in Fig. 1, the iron and steel production, which had attained the highest peak of 7,765,000 short tons of steel in 1942, was practically shut down in 1946. General stagnation also prevailed in iron and steel fabrication.

The national policy which placed stress on increasing the production of iron and coal, starting in 1947, prepared the way to recovery. The brisk market brought by the Korean war in June 1950 resulted in a boom in the iron and steel industry. It produced 6,952,000 short tons in 1952. However, in 1952 a balance of supply and demand was re-established; mainly influenced by the prolongation of the rearmament program of the Western countries, iron and steel production of Japan has leveled off.

Equipment – As far as the absolute capacity of production is concerned, no shortage is recognized in the Japanese iron and steel industry (see Table I). No small portion of the present equipment is, however, superannuated or was overworked during the war. Modernization has been under way since 1951 by introducing up-to-date equipment, for which 30 billion yen ($83,500,000 when 360 yen = $1.00) has already been expended out of the estimated amount of 90 billion yen ($250,000,000) required under the Three-Year Rationalization Plan.

Additions planned to the capacity after this year (1952) are entirely of the most modern type. As for rolling equipment, completely up-to-date and efficient mills will manufacture 2,200,000 additional tons of plates, hoops, wire rods, cold strip, and pipe, at a price which will fully compete on the international market.

Table I – Capacity of Japanese Iron and Steel Industry
(Unit: Thousands of Short Tons)

Department	Capacity Jan. 1, 1952	Capacity Added in 1952	Capacity at End of 3-Yr. Plan
Blast furnace	3,921	803	5,016
Openhearth	6,637	787	7,538
Hot finished steel	12,271	220	13,180

Raw Materials – Japan has a meager supply of home-produced raw materials. Overseas sources are absolutely necessary. As the production of blast furnace pig iron increased after 1951, the prewar dependence upon foreign iron ores and coking coal returned so that we now import 80% of the necessary iron ore and 42% of the coking coal.

Prewar Japan relied heavily on the Chinese mainland for these necessities. Owing to the changed international situation, we now get our iron ores from the U. S. A., Canada, and India. (We must get about 1,500,000 tons from the U. S. A. and Canada in 1953.) Japan must expect a greater portion of imported coking coal (even up to 3,000,000 tons annually) from the distant east coast of the U. S. A., with the exception of a small amount (about 50,000 tons of rather low grade) from India.

Since imports were blockaded during the war, production of iron ores at home sharply advanced from 2,150,000 short tons in 1942 to a peak of 3,850,000 in 1944. Such a high production was achieved by entirely neglecting the economics. Viewed from the proper basis of production and quality, the production of Japanese iron ores is to be limited to 1,100,000 tons annually.

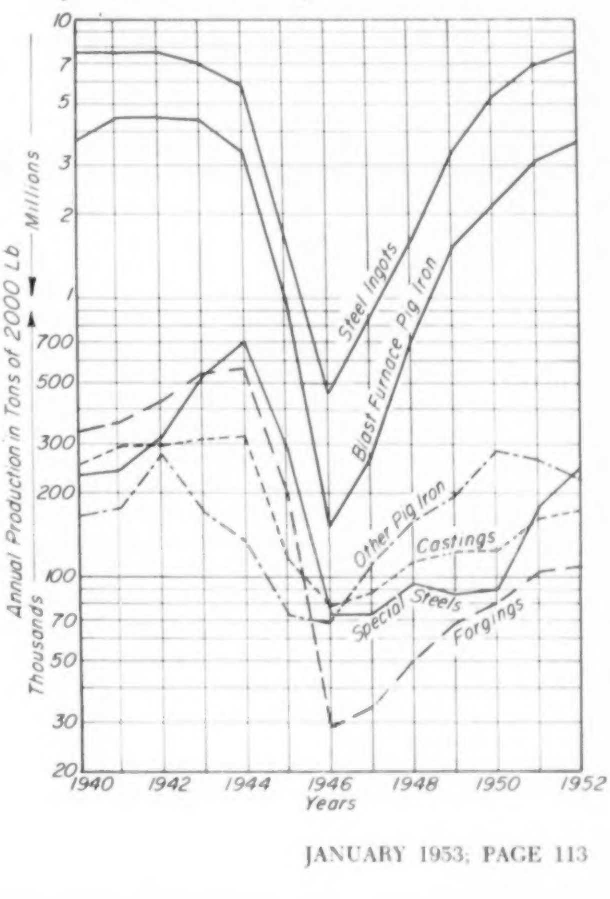
Pyrite cinder and sand iron ore are widely used, amounting, of late, to 770,000 and 330,000 tons respectively. Moreover, experimental use of other iron minerals is now under way.

During 1935 to 1939, 1,500,000 to 2,750,000 tons of scrap iron were imported. This supply was also suspended during and after the war, and in view of the postwar condition in other steelmaking countries, we cannot expect a large amount from abroad. Recently Japan is getting an annual supply of 225,000 to 330,000 tons of scrap iron from Korea and the Southeast Asian area. Immediately after the war the supply of scrap iron from war-torn areas in Japan was estimated at around 10,000,000 tons, but this source is now nearly exhausted. Consequently, even taking account of 2,650,000 tons from this supply, besides the self-producing scrap within factories and steel mills, it is necessary to raise the pig iron charge in the openhearth furnaces, and hence increase pig production by blast furnaces in order to maintain the proper level of steel production.

Prospects for 1953 – In fiscal year April 1953 to March 1954, 4,600,000 tons of blast furnace pig iron are in prospect. In terms of steel, 6,150,000 tons of openhearth steel and 1,550,000 tons of converter and electric furnace steel are estimated. The estimated production of hot rolled carbon steel, forgings and castings is 5,560,000, 165,000 and 220,000 tons respectively. As remarked above and shown in Table I, a big increase is expected in blast furnace production.

The demand for alloy steel is expected to increase, principally due to the demands of the United Nations Forces in Korea and the U. S. Security Forces in Japan.

Fig. 1 – Annual Production (1952 Estimated) of Various Units of the Japanese Iron and Steel Industry Since 1940. Note logarithmic vertical scale



Technical Development Needed

The main items of domestic demand in 1953 are 950,000 tons for machinery, 420,000 tons for shipbuilding, 265,000 tons for land transportation, 220,000 for generation of electric power, 275,000 for civil engineering, and 110,000 tons for coal mining. In such items as machinery and the generation of electric power, a 30% rise is expected for each as compared with 1952.

As to supply, we expect to make 1,200,000 tons of steel plate, 825,000 tons of steel sheet, 1,000,000 tons of bars, 650,000 tons of structural shapes, 450,000 tons of wire, 285,000 tons of steel tubes and 200,000 tons of hoops. No significant change is being witnessed in 1953 as compared with 1952.

NONFERROUS AND LIGHT METALS

In view of its small territory, Japan is favored with mineral resources, which – side by side with other factors – enabled this country's nonferrous metal industry to attain an international reputation in the prewar days. The strategic importance of these metals before and during the war warranted active measures for protection and promotion, and production was sharply increased. However, the foundation of this industry remained very frail and unstable. Insufficient technical backing of the increased production and inadequate fostering of effective demand, as well as wasteful operation of the mines – inevitable as they were in that period – now erect important obstacles to postwar metal production.

The exclusive and protective policy, both prewar and postwar, has weakened the basis of this industry. Various recent measures have failed to raise this industry to where it can compete in the international market. Thus, one cannot fairly claim any notable technical progress, although it is becoming apparent that this is a matter of urgent necessity.

At present, smelting capacities are 123,000 short tons of copper, 52,000 tons of lead, and 85,000 tons of zinc yearly. The general position in fiscal 1952 is about as follows:

Copper: Japan will produce 55,000 tons of copper from domestic ores, 11,000 tons from imported ores, and 37,500 tons from reworking slag dumps. The principal demand will be for 75,000 tons of electric wire and 23,000 tons of sheet and bars.

Lead: 17,500 tons of lead will be smelted from domestic ores and 7500 tons of secondary and scrap lead will be recovered. However, about all of the 3000 tons will be used, in addition, from the relatively small national inventory. This lead will be used as follows: 11,000 tons by the electrical industry, plus 7500 tons for storage batteries; 3300 tons for sheet and pipe and 3000 tons for chemicals.

Zinc: Japan will produce about 55,000 tons of electrolytic zinc and 22,000 tons of distilled zinc in fiscal 1952. Principal uses will be 42,000 tons for galvanizing steel sheet, 13,000 into brass products, 9000 tons into oxide.

Refining Techniques – Significant postwar developments consist in the intensified utilization of idle resources and intensified scrap collection, as well as the industrial rationalization by advanced techniques from overseas. Since the mines were overworked during the war, their output has sharply declined while the costs have increased.

The so-called complex ores (such as those of lead and zinc, or of copper, lead and zinc) comparatively abundant in Japan, have mostly been left untapped, though the metals have sometimes been extracted singly. Recently, a large-scale operation on arseno-pyritic ores has started, using the "Fluo-Solid" process.

Zinc contained in old smelter slags is now being extracted by the fuming process, well known in western American smelters.

Formerly sulphurous gas from the roasting of sulphide ores caused much smoke damage. Today this gas is converted to sulphuric acid. (Pyrite cinder, an important byproduct of the manufacture of sulphuric acid, is now an important iron ore.)

Satisfactory results have been achieved in the experimental use of oxygen and oxygen-enriched air in the direct smelting of copper concentrates. Some 30% of our zinc is recovered in horizontal retorts by the distillation process; conversion to vertical retorts is now taking place.

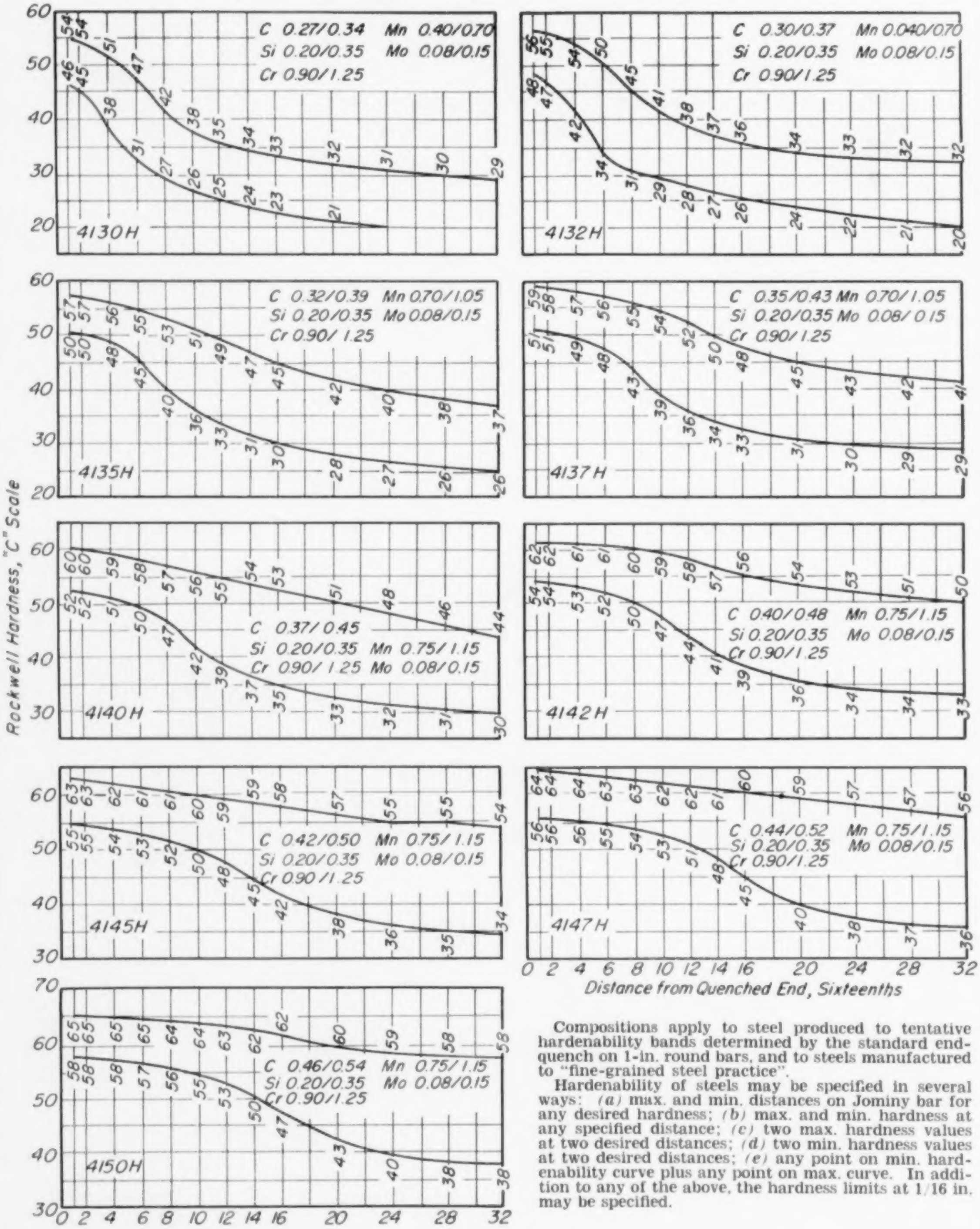
Intensive research on titanium has been under way. Recently, Japanese metallurgists succeeded in recovering it from iron slags by the chloride method. A commercial plant is under construction.

Generally speaking, the production of light metals in Japan has been retarded by various factors, the reparations problem being an important one. Magnesium production is in abeyance. As for aluminum production, which is a comparatively new industry to Japan, techniques of high standard were adopted at the beginning.

(Continued on p. 178)

Hardenability Bands for Tentative Standards

Series TS41XXH, Approved November 1952



Compositions apply to steel produced to tentative hardenability bands determined by the standard end-quench on 1-in. round bars, and to steels manufactured to "fine-grained steel practice".

Hardenability of steels may be specified in several ways: *(a)* max. and min. distances on Jominy bar for any desired hardness; *(b)* max. and min. hardness at any specified distance; *(c)* two max. hardness values at two desired distances; *(d)* two min. hardness values at two desired distances; *(e)* any point on min. hardenability curve plus any point on max. curve. In addition to any of the above, the hardness limits at 1/16 in. may be specified.

By TOM BISHOP, Editor, "Metal Treatment and Drop Forging", London, England

Notable Advances in Fabrication Methods and Metal Applications

To condense into a few pages a complete account of postwar developments in European metal engineering is obviously impossible. One aspect alone – materials for high-temperature applications – occupied a large tome recently published by the Iron & Steel Institute. The present article must be limited in scope to a few outstanding examples relating to steels and high-temperature alloys.

Surface diffusion processes offer a range of most interesting industrial possibilities, for while carburizing improves the wear resistance of steel components, there is no improvement in corrosion or heat resistance. Considerable research has been carried out in England on this subject. Early work was mainly devoted to the diffusion of metals having a comparatively low melting point, such as aluminum diffusion (or calorizing for improved heat resistance) and zinc diffusion (or Sherardizing for atmospheric corrosion resistance).

For resistance to acids and certain other corrosive media, the American work of Ihrig on silicon diffusion (Ihrigizing or siliconizing) is of particular interest. The surface of many metals can be enriched with silicon by heating in an atmosphere containing $SiCl_4$ vapor. In the absence of a reducing gas, the dominant reaction is replacement, that is,

$$2M + SiCl_4 \rightleftarrows 2MCl_2 + Si$$

In the presence of hydrogen, there is an additional reduction reaction:

$$2H_2 + SiCl_4 \rightleftarrows 4HCl + Si$$

Apparatus has recently been developed at Fulmer Research Laboratory designed to siliconize metal surfaces under conditions in which the balance of the above reaction is changed by the use of mixtures in various proportions of a neutral gas such as nitrogen and the reducing gas hydrogen. The rate of penetration of silicon into the metal surface can also be varied by altering the temperature of the water bath which heats the liquid $SiCl_4$. Metals siliconized in this way show improved resistance to wear and to attack by acids and corrosive media.

Chromizing – It appears that, both from a theoretical and from a practical point of view, chromium diffusion promises outstanding all-round performance. Since 1940 considerable technical progress has been made in Germany and Britain, although on different lines.

Broadly speaking, research in Germany was devoted chiefly to metallurgical problems such as the selection of special steels and furnace equipment to suit an improved but static technique. Effort in Britain was directed toward evolving and modifying the chemical factors to suit standard steels and conventional furnace equipment. In Britain, two processes are commercial, one by Metal-Gas Co. Ltd. (B.D.S. process which depends upon the action of chromous chloride in a reducing atmosphere) and the other by Diffusion Alloys Ltd. (D.A.L.). In France, there is "Dikrom" as carried out by Société des Produits de Cémentation, and further techniques devised by the Office National d'Etudes et de Recherches Aeronautiques (known as ONERA).

The German firm of August Thyssen developed special Inkromstahl (I.K. steels) for the B.D.S. process. The first, I.K.1, had the following composition: 0.10% C, 0.30% Si, 0.50% Mn, 0.45% Ti. The titanium acted as a carbide former, and titanium carbide precipitated as particles within the grains (instead of around the boundaries as iron carbide would naturally occur), thus removing any barrier to the normal diffusion of chromium.

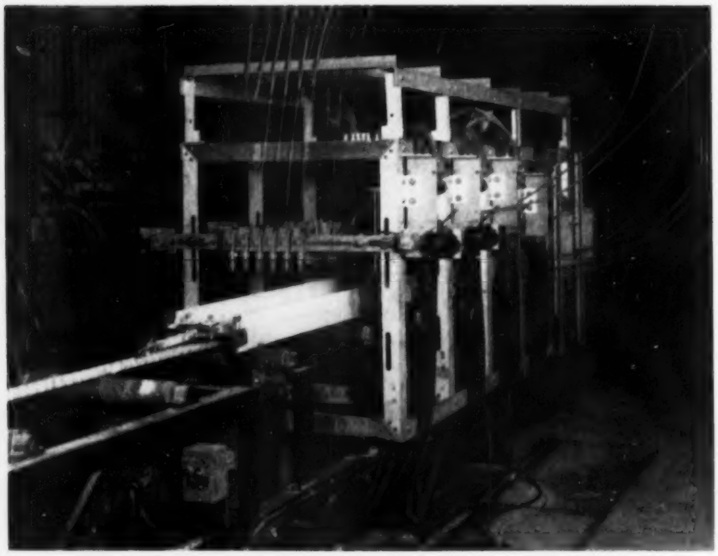


Fig. 1 – Automatic Spraying Machine for Metallizing Structural Shapes (Metallization, Ltd.). See also Metal Progress *for November 1952, p. 100*

However, while I.K.1 was satisfactory for chromium diffusion, from an engineering standpoint its mechanical properties were poor. Other steels were developed containing a high proportion of alloying elements. Typical compositions of some of these are as follows:

ELEMENT	I.K.3	I.K.25	I.K.85
Carbon	0.10%	0.09%	0.15%
Manganese	>3.0	0.35	–
Silicon	–	1.0	0.8
Chromium	–	2.5	7.5
Vanadium	–	0.17	0.5
Copper	–	0.2	–
Molybdenum	–	–	1.2

Such steels fall within Group 1 of Table I, classifying the steels and irons appropriate for chromizing. Processing temperatures depend on thickness of parts and required characteristics of case.

Chromized steel parts are now used in pumps and measuring and control devices handling gasoline, and generally give good service in contact with petroleum products. Stainless steel has had its resistance to corrosion by oil ash improved after chromizing, but the thickness of the coating may be the limiting factor. Chromized mild steel jigs for holding parts during salt-bath heat treatment have been very successful; the coating prevents carburization of the mild steel core, so the jigs do not harden when quenched; they distort less than cast alloy jigs, and can be straightened if necessary.

The foregoing remarks apply particularly to chromized mild steel and low-alloy steels. In general, other steels have inferior properties.

The chromium carbide type of coating obtained on high-carbon steels, some toolsteels, and cast iron has excellent corrosion resistance under workshop conditions, and it is noticed that tools chromized to impart wear resistance do not rust. The coating is rather inert chemically, and shows some resistance to sulphuric acid. Good corrosion resistance can be obtained by chromizing cast iron, but the quality of the material must be specified; on certain castings the coating may be very porous and the underlying layers will rust. The Meehanite type of cast material and malleable castings can be considered as "steels" for chromizing purposes.

Chromized surfaces do not "tin" easily; specialized flux enables them to be soldered. Soldering jigs made from chromized mild steel do not pick up solder. In contact with molten lead, they do not corrode, and chromized pots for lead baths have been used with success. Ordinary dies for die casting zinc-base alloys quite quickly pick up a deposit of zinc, which spoils the appearance of the castings, and the dies must be cleaned periodically, whereas chromized dies can be in operation very much longer before cleaning is required.

HIGH-TEMPERATURE ALLOYS

While much information concerning latest designs of gas turbines – popularly known as jet engines – is withheld, some of the British engineering and metallurgical periodicals have been able to publish much data on such

Table I – Steels and Irons for Chromizing by $CrCl_2$

GROUP	MATERIAL	PROCESSING TEMPERATURE
Group 1	Plain or alloyed steels, C <0.30%	1750 to 2000° F.
Group 2	Plain steels, C 0.30 to 0.55% Alloyed high-carbon steels Alloyed steel castings, C <1.5% Malleable castings	1650 to 1825
Group 3	Plain high-carbon steels Iron castings	1475 to 1750

outstanding advances in aeronautics as the Comet airliner, the Delta-Wing jet bomber, the Hawker "Hunter", the "Canberra", the "Javelin" and many others. One of the most powerful of these aircraft units – the "Olympus", built by Bristol Aeroplane Co. Ltd. – has a rating of 9750 lb. thrust or better. These aeronautical achievements are based on advances in the field of metals subject to both high temperatures and high stresses. This is a field of metallurgy in which Britain can be justly proud.

Gas turbines, of course, are not exclusively the property of aircraft. The American petroleum industry was quick to see their utility for pumps and prime movers where natural or by-product gas might go to waste. Gas-turbine-driven locomotives are under extensive road tests in various countries. In Britain interest also naturally gravitates toward shipping. One tanker, the "Auris" whose propulsion plant is half diesel, half gas turbine, made several transatlantic crossings during 1952, some on power from the gas turbine exclusively. Results were so favorable that the owner, Anglo-Saxon Petroleum, has ordered an 18,000-ton tanker powered by two 4150-hp. gas-turbo-alternators. Of more popular interest, perhaps, is the rumor that the Cunard Line has on the drawing board plans for a gas-turbine liner with aluminum superstructure to give service comparable to the 81,000-ton "Queen Mary".

Alloys for Disks and Blades – General practice both in Britain and America is to use disks of austenitic steel. Americans use frequently a composite disk – austenitic rim welded to a ferritic steel center. One British firm of engine manufacturers has consistently used ferritic steel disks, air cooled at the rim.

Nominal compositions of alloys for disks and blades for aircraft gas turbines are given in Table II; creep strengths of many of these were tabulated in *Metal Progress* data sheets for November and December 1951. While American engines have used many of the disk alloys, G.18B is almost always chosen in Britain (except for the ferritic disk mentioned above).

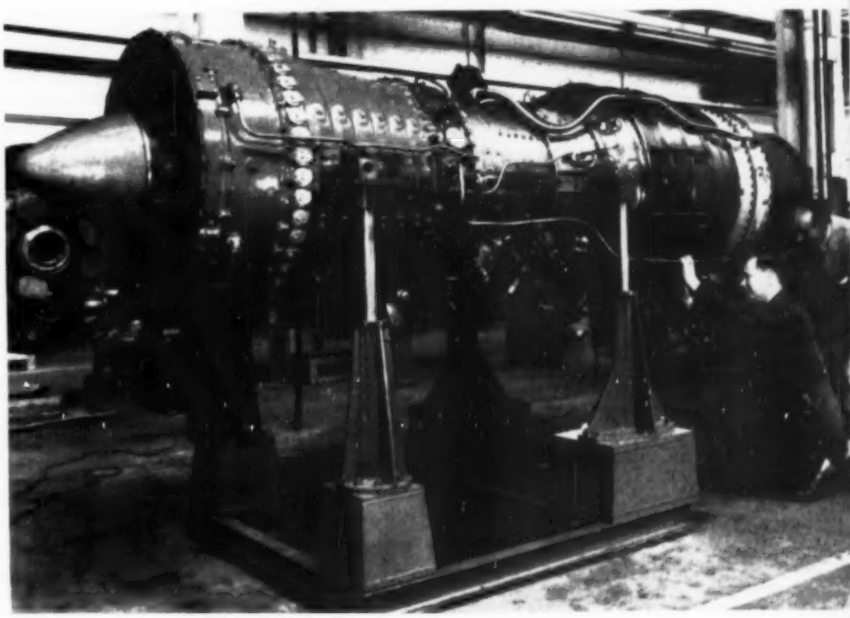
Materials for turbine blading vary with life and service. A blade which may last indefinitely in a low-temperature, low-efficiency turbine in a petroleum refinery would not be suitable for a high-duty aircraft engine even though the expected life in hours may be comparatively short. In the latter case, greater emphasis must be placed on creep resistance, since speeds, centrifugal stresses and temperatures are very high.

It is known that efficiency of the gas turbine increases much faster than the operating temperature – at least in the ranges used at present – and that the safe limit seems to have been reached in alloys of our available refractory metals. Likewise the supply of the best of these metals is hardly adequate to make the expected number of engines. Various schemes for cooling the blades and buckets introduce many undesirable complications, so the present line of development seems to be toward mixtures of metals and metallic compounds. One example is titanium carbide cemented with cobalt. Actual achievements in this direction are still hidden by the veil of "security".

FABRICATION OF BLADES

Where blades are manufactured from bar stock, it is customary in Britain for the steelmaker to supply descaled or etched bar (to facilitate inspection) in the annealed or in the solution treated and aged condition. No fur-

Fig. 2 – Bristol "Olympus" Turbojet Engine of 9750-Lb. Thrust, for Use in Canberra Bomber



ther heat treatment is normally required. This applies equally to cold worked bars, which may have been manufactured by cold drawing, cold stretching, or rolling at, say, 1100 to 1300° F.

There are no major advantages in machining the austenitic steels in the nontreated condition.

The majority of moving turbine blades for aircraft engines are made from drop forgings which have a generous allowance for final machining. While precision forged or coined blades can be made of a number of the materials, the difficulties increase with the more highly alloyed austenitic analyses. Disadvantages are heavy die wear and the inadequacy of prevailing heat treatment facilities.

Apart from the question of the superior macrostructure of a forged blade, the manufacturing operation readily reveals defects which would normally escape inspection were bar stock to be used. In many of the more complex austenitic steels, however, working may cause an undesirably large grain growth during the final heat treatment when the amount of deformation coincides with a critical amount of work in certain temperature ranges. Such undesirable large grain size is difficult to avoid, but it can often be limited by a strict attention to forging temperature and limiting the amount of work done in any one heat.

The stainless ferritic types of steel forge well, both in regard to ease of deformation and freedom from bursts, but since they air harden strongly they require annealing or tempering immediately. The austenitic steels vary as regards forgeability but are all substantially stiffer to work when compared with the ferritic types. The stabilized 18-12 chromium-nickel steels do not generally require special attention and are not particularly susceptible to abnormal grain growth. The more complex austenitic steels are somewhat more resistant to hot deformation than the simple 18-12 steel. The types with higher creep resistance, such as 337 and R.ex467, need greater care in forging if center bursts are to be avoided. Austenitic steels do not require any special precautions in regard to cooling from forging temperature. The ferritic steels can be forged from a maximum of 2200° F., but the temperatures for austenitic steels should be restricted to a maximum of about 2100.

Forging stock is normally supplied as centerless ground bars of diameter suitable to the particular blade. Ground bars can be readily inspected with or without etching. Required lengths are sawed or ground with thin abrasive wheels, thus offering a rough and ready means of subsurface inspection.

Initial forging usually consists of a preliminary upsetting and drawing out of the material; this acts as a check on the quality. Subsequently, the blank is shaped under a small forge hammer, using swages to form a dumbbell pattern, depending upon the blade form. The rough form is then transferred to the actual drop hammer for the final die forging.

TOOL AND DIE STEELS

The scarcity of certain strategic elements still creates great interest in possible substitutes for established toolsteels, especially of the high speed type. In Germany, R. Scherer and W. Connert have suggested, on the basis of turning tests, that increased vanadium will compensate for limited reductions in tungsten. Attempts to use chromium in place of tungsten have not been successful, but work on aluminum and nitrogen together in steel have given encouraging results. The introduction of cobalt up to 18% improves hot hardness and "cuttability" of super high speed steels. Rykik has described a Russian process for milling cutters in which a hard facing of high speed steel is applied to a low-alloy cutter by an electric arc process in which flux-coated rods of proper analysis form the electrodes.

The effect of metallic and carbide segregation on the cutting power of high speed steel tools has been investigated in England and has been of considerable commercial interest to the U. S. as well. Microradiography shows that while cobalt and molybdenum do not have any appreciable effect on the carbide segregation, 4% vanadium seems to reduce the carbide size and makes the distribution more uniform. The effect of heat treatment (austenitizing and tempering) is to take the smaller particles of carbides and the heavy metals into solid solution. Precipitation appears to occur on the remaining carbides rather than by re-forming about additional nuclei and consequently the range of size of the carbides is reduced – that is, the carbides are more uniform in size. Diffusion of the heavy metals appears to be more complete than examination with the optical microscope would suggest.

Under certain conditions, there can exist in these steels zones which are almost devoid of the heavy metals. It is considered that this effect may be caused by nonmetallic impurities in the steel, such as sulphur, phosphorus, or

the usual gases. (On the other hand, this effect could be caused by the presence of nonmetallic inclusions of low absorbing power for the radioactive materials added during the experiments.) In this instance, however, optical micro-examination did not reveal the presence of any massive inclusion stringers. It is considered that these zones can act as planes of weakness in the finished tool, particularly at the high temperatures that are developed close to the cutting edge.

DIES FOR EXTRUSION

Interest has recently been stimulated in extrusion by the production in 1952 of the latest extrusion units in Britain by Loewy and by Fielding and Platt for extruding nonferrous metals. Further, Jacques Sejournet, general manager of the French company, Comptoir Industriel d'Etirage et Profilage de Métaux, has proposed Fiber-Glass as a lubricant for hot extrusion of steel and this idea is operating on a pilot-plant scale on both sides of the Atlantic. Interest largely centers on the metallurgical condition of the material to be extruded, the dies, and the design of the press.

An important conference organized by the Institute of Metals in Birmingham, England, early in 1952 discussed tool and die materials for extruding nonferrous metals. A tool user at the meeting was of the opinion that an ideal tool material would be one which could stand up to the work, even when heated to the billet temperature. Such a material would extrude stock with uniform properties end to end. However, no known material would work at the temperatures used in extruding copper-base alloys under present operating conditions. For many years it had been standard practice to use an 8 to 10% tungsten steel for dies, mandrels, back pads and pressure plates – if necessary for the bolster or holder as well, although for this a nickel-chromium steel was often adequate. Additions of cobalt, nickel and other metals had been tried, but these had not given any significant improvement in die performance. The Imperial Chemical Industries, Ltd., has therefore made its own of cast tungsten carbide. By 1948 other British makers were prepared to precision cast dies in hard materials, and obtained sufficient accuracy for many dies to be used without any machining.

This leads to the further question of the optimum hardness for steel tools for hot work. A Brinell hardness of 380 was suggested in a recent productivity report, but one user suggested that he would prefer his mandrels to be 100 numbers harder than this. A maker agreed that 450 Brinell would be better than 380, and his object was to give the highest hardness which could be retained in service. This was normally obtained by tempering slightly above the working temperature. It is questionable whether hardness is the best measure of abrasion resistance; tungsten steel in the annealed condition had given better performance than when heat treated, and elsewhere copper had been extruded through annealed nickel-chromium steel dies.

Table II – Nominal Compositions of Steels and Alloys Used for Gas Turbine Disks and Blades

Material	C	Si	Mn	Ni	Cr	Mo	W	Co	Others†
			Nominal Composition of Disks						
G18B	0.4	1.0	0.8	13.0	13.0	2.0	2.5	10.0	3.0 Cb
16-25-6	0.09	0.9	1.5	25.0	16.0	6.0			0.18 N
19-9DL	0.3	0.6	1.0	9.0	19.0	1.3	1.3		0.4 Ti; 0.4 Cb
Discaloy	0.05	0.7	0.7	25.0	13.0	3.0			2.0 Ti; 0.5 Al
Mo-V	0.20	0.30	0.50	0.3	0.2	0.65			0.25 V
Cr-Mo-W-V	0.17	0.30	0.50	0.3	3.0	0.50	0.50		0.70 V
R. ex 448*	0.15	0.75	0.75		11.5	0.75			0.15 V; 0.45 Cb
R. ex 467*	0.20	0.70	1.0	9.5	14.5	2.0			0.80 Ti; 2.5 Cu
			Nominal Composition of Blades and Buckets						
Nimonic 80A	<0.10	<1.0	<1.0	Rem.	19.5			<2.0	2.25 Ti; 1.0 Al; <5.0 Fe
Nimonic 90	<0.10	<1.5	<1.0	Rem.	19.5			18.0	2.25 Ti; 1.3 Al; <5.0 Fe
S-816	0.40	0.6	1.3	20.0	20.0	4.0	4.0	42.0	4.0 Cb; 3.0 Fe
G-32	0.27			10.5	19.0	2.2		46.5	3.0 V; 1.4 Cb
FCB(T)	0.10			12.0	18.0				1.2 Cb
326	0.25			17.0	16.0	2.5		7.0	1.8 Cb
337	0.20			17.0	16.0	3.0		7.0	0.8 Ti; 3.0 Cu

*R. ex 448 and 467 are also used for blades. †Iron is remainder except for the Nimonics and S-816.

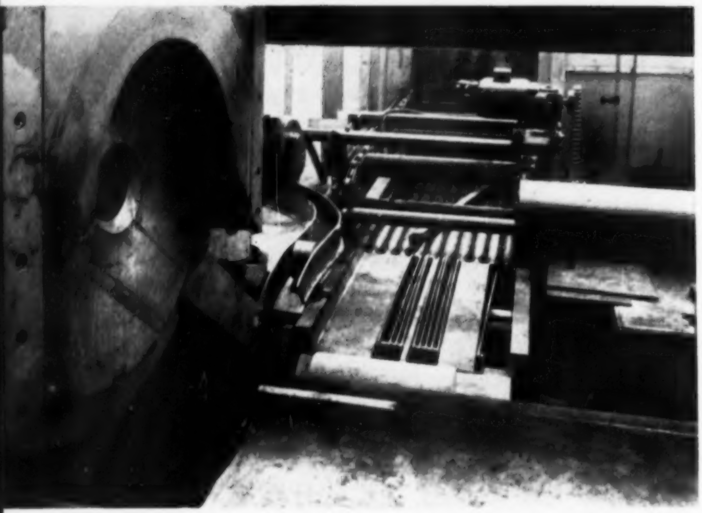


Fig. 3 – Fielding & Platt 2000-Ton Extrusion Press for Nonferrous Metals in Use by Aston Chain & Hook Co., Ltd. View shows conveyer from heating furnace to press, with billet in center foreground ready for lifting to axis of cylinder

Varied comments were made at this Birmingham conference by those who had tried nitrided dies. Some reported considerable improvement in life; another that the die had rolled-in badly at first, and had cracked after about 20 extrusions. It was pointed out that nitriding may help to prevent a tempering effect at the die's surface, but it was most essential that the main material of the die be able to withstand the working stresses.

A maker inquired if there was any steel in the productivity report which users would like to try, and attention was immediately directed to Halcomb 218 (0.4% C, 5.0% Cr, 1.35% Mo, 1.0% Si, and 0.35% V). The hardness is given as Brinell 362 to 381. Several users reported that they had recently used steels of this type, usually containing rather more vanadium. One firm had used material with the following analysis: 5.5% Cr, 1.0% V, 1.3% Mo and 1.0% Si. This was a great improvement for mandrels over a high tungsten steel, and was also much cheaper.

Strong, Heat Resistant Alloys and Metallic

In France, as in all industrial countries, much attention has been given to the commercial production of metals and ceramics for high-temperature service. Temperatures and stresses of machines and equipment are constantly rising; consequently, much research has been done in this field during the last generation. It has resulted in notable improvements in alloys (a field which has been followed by *Metal Progress*) and has now branched out into metal oxides, carbides and borides – either singly or in combination, and usually cemented together with a metallic binder.

It is intended to review briefly all these fields.

The engineering materials under consideration must resist static and dynamic stress. In certain uses they must never deform greatly – some of them hardly at all. They must also resist chemical attack of heated air or combustion gas. Likewise, the structure must remain practically unchanged during its lifetime, so that its properties will not vary. No fracture may appear in service. Forging and machining must not be too difficult. Finally, for pieces that will rotate at great speed, such as the blades of gas turbines, a low specific gravity is needed to lessen the centrifugal forces.

FERRITIC STEELS AND ALLOYS

Although ferritic alloys are by their nature the least resistant to creep, they can still be used at relatively low temperatures, as in steam turbines, or in more exacting apparatus where the parts can be cooled artificially. For this reason it was considered necessary to perfect this type of alloy.

Ferritic steels have the following advantages over austenitic steels:

1. High elastic limit at room temperature.
2. Low coefficient of expansion, which mitigates the thermal stresses.

3. Ease of forging and heat treatment.
4. Relatively easy fabrication.
5. Economy of strategic elements.
6. Relatively low price.

On the other hand, they present the following disadvantages: *(a)* Creep diminishes rapidly above 1000° F.; *(b)* notch sensitivity is in general greater at temperatures below 750° F. than is true of austenitic steel; *(c)* welding is generally more difficult.

Chemical Composition – Molybdenum is the alloying element most active in giving creep resistance to iron; chromium gives resistance to oxidation; nickel is indispensable for the hardening of large pieces by heat treatment. Therefore, the ferritic steels usually made were Cr-Mo steels and Ni-Cr-Mo steels. Tensile strength at high temperature was increased by additions of vanadium. Likewise, half of the molybdenum may be replaced by tungsten.

Thus the following steel has already been used by the Germans during the war for rotor disks of turbo-jets: 0.2% C, 3.0% Cr, 0.4% Mo, 0.4% W and 0.85% V. It proved to be very good at temperatures of 1000 to 1200° F., and was a useful extension of the possibilities for

Combinations

ferritic steels. This heat treated steel is not susceptible to fatigue failure starting at slight notches. Its resistance to carbide coalescence after prolonged stay at temperatures of use makes this steel especially interesting for land and sea turbines.

Columbium was also added to ferritic steels, to induce precipitation hardening after solution treatment. This is effective even if the carbon content is very low. For example, note the following composition which has been used in Germany: 0.05% C, 0.45% Mn, 0.8% Si and 1.0% Cb. Columbium has also been added to high-alloy steels more resistant to oxidation – such as the 12% Cr stainless steel – to increase their creep resistance. Such a steel would give excellent service up to 1200° F.

Columbium-bearing steels need a higher hardening temperature than others, to put the columbium compounds into solution – they being less soluble than the carbides of chromium

Ferritic Vs. Austenitic Alloys

and molybdenum. Temperatures in the neighborhood of 1925 to 2100° F. are specified for steels with only a small percentage of chromium; even higher austenitizing temperatures are called for if the steel contains 12% Cr.

Unfortunately, columbium is a rather scarce metal, and its value as a hardener of cobalt-base alloys is so great that little of it can be spared at present for the ferritic steels on the low end of the scale.

Heat Treatment – Ferritic steels exhibit a gamut of structures, obtained by the various heat treatments. These are not equivalent as far as mechanical properties at high temperatures are concerned. French metallurgists have given this subject particular attention. (See *Metal Progress* for December 1951.)

The Future – Progress to be expected for this type of steel should be along two lines – use of new alloying metals, and discovery of more appropriate heat treatments. The addition elements are partly dissolved in the ferrite at service temperatures, but usually exercise their prime effect when finely precipitated as carbides or intermetallic compounds. The nature of these precipitates, on which the resistance of the steel in large part depends, can be determined after they are separated by methods of electrolytic extraction. There is plenty of work still to be done in this field.

AUSTENITIC STEEL AND ALLOYS

The face-centered cubic crystal – austenite – has proven much more resistant to flow than the body-centered cubic (ferritic) structure. Besides, austenite can dissolve many alloying elements at high temperatures which tend to precipitate in the form of carbides or of intermetallic composites when temperature falls below 1300° F. For this reason the structure is amenable through various heat treatments to hardening processes – precipitations which reinforce considerably the strain resistance of the matrix. Furthermore, the finely dispersed precipitate is very resistant to coalescence (if it is judiciously chosen) and so holds its strength during prolonged stays at service temperature.

The increased creep resistance obtained in

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Precipitates Added for Creep Resistance

solid solution alloys through heat treatment is not due solely to precipitation at the time of reheating or during high-temperature service, but also to alloy elements remaining in solid solution in the matrix, thus strengthening it by the heterogeneity of the crystalline structure that is induced by the presence of such "stranger" atoms.

With these structures two types of phases are to be improved before the most resistant alloys can be produced – namely, the basic matrix and the precipitated particles.

In the austenitic stainless steels, the basic matrix is a face-centered cubic crystal built up of iron atoms, within which numerous nickel and chromium atoms appear at positions which otherwise would be occupied by iron. They render the austenite a very stable crystallographic entity and the steel very resistant to oxidation. But the two next metals in the periodic sequence (therefore chemically very similar to iron) form gamma solid solutions with iron and with each other in all proportions. Such ternary austenitic alloys have strength properties at high temperatures greater than those of the better-known austenitic stainless steels. These metals are nickel and cobalt. For this reason nickel-base and cobalt-base alloys have been intensively studied; this opens up a vast field of exploration by varying iron, nickel and cobalt in the basic matrix.

Besides, to reinforce the intrinsic properties of this matrix at high temperatures, additions of various elements were put in solid solution by heating to high temperatures (around 2100° F.). After rapid cooling, these were precipitated as various compounds by prolonged reheating at medium temperatures (around 1200 to 1500° F.). These precipitates were hardening phases and induced resistance to flow and creep. These precipitates, which in general are either carbides or intermetallic compounds, are now under intensive research – indeed they constitute the principal field of research for perfecting our present high-temperature alloys.

The elements or reinforcing alloys already used are tungsten, molybdenum, titanium, columbium, aluminum and tantalum. (Nitrogen might also be included, since it can replace part of the carbon atoms in the precipitated carbides.) The precipitates must not only increase the tensile strength and creep resistance at high temperatures in the matrix; they must also resist coalescence during service at these high temperatures. Furthermore, excess addition element remaining dissolved in the alloy must also improve the properties of the matrix permanently. Studies already made show that, from these points of view, complex composites produced by two or more additions are more efficacious than those produced by one alone. Consequently, many commercial alloys use several of the metals named above.

The categories may be listed as follows:

Austenitic Steels – These are extrapolations of the classic 18-8 Cr-Ni stainless steel, especially by increasing the nickel content to more than 25%. This makes the austenite very stable even after cold work, and in spite of the presence of much chromium (necessary for oxidation resistance) and of the precipitation additions – all alpha-forming elements with the exception of nitrogen. Thus, compositions are about as follows: 14 to 20% Cr, 10 to 30% Ni, 6% Mo, with additions of W, Cb and Ti possibly as high as 4%, Al up to around 1%, and nitrogen to about 0.4%.

Alloys of Nickel Base – These alloys are derived from the former alloy with 80% Ni, 20% Cr for wire and strip resistors. To this basic alloy the elements creating precipitants are added as described above. Typical is the "Nimonic 80" commonly used in British jet engines: 20% Cr, 2.5% Ti, 0.8% Al, 0.6% Mn, and the rest nickel.

Alloys basically of nickel with aluminum and molybdenum added have recently been studied in the United States. About 8.5 to 9.0 times as much nickel as aluminum is indicated; the desirable composition would be 70% Ni, 8% Al, 21.5% Mo. This gives excellent castings by the lost-wax process.

Alloys With High Cobalt all have between 20 and 30% chromium; the respective proportions of nickel, cobalt and iron vary considerably. Variations up to 20% Co exist, and nickel may vary from 20 to 60%, the iron varying inversely. Another group of alloys contains about 65% of nickel plus cobalt, the cobalt varying from about 30 to 50%. Finally, for investment castings, alloys with 62 to 65% cobalt exist – specifically, "Vitallium", containing 62% Co, 28% Cr, 6% Mo or (6% W plus 2.5% Ni) – alloys closely related to the American Stellites, well known as cutting tools, but very low in carbon content.

It is not possible to elaborate further on these varied alloys of extreme interest.

The Future – It is hardly to be expected that the maximum temperature of service can be greatly raised for metallic alloys. Minor improvements may be looked for if the optimum

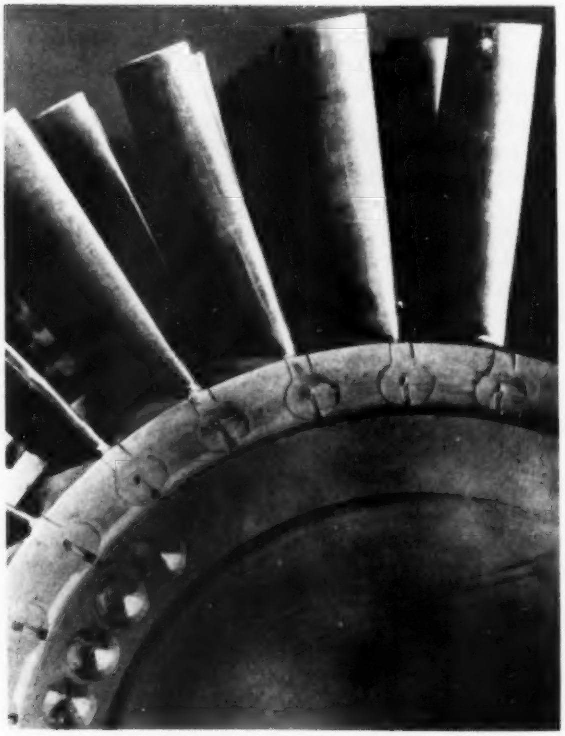


Fig. 1 — Compressor Disk With Keyed-in Blades for a Westinghouse 19B Jet Engine

equilibrium can be found between the basic Fe-Ni-Co alloy of the matrix and the quality of the hardening precipitates (carbides or intermetallic compounds). This field is vast, and can only be prospected slowly because of the length of time necessary for creep testing and for determining corrosion resistance.

To increase the resistance of a metallic part to corrosion and stress at high temperature, metals with a higher melting point must be used in greater measure. This is true for chromium, tungsten and molybdenum. Chromium, whose melting point is 3425° F., is particularly promising; it is actually very resistant to oxidation (tungsten and molybdenum are not) and besides is rather abundant and would not seem at the moment to pose any strategic problem. Thus chromium-base alloys are beginning to be studied more intently. Of these, chromium-iron alloys seem the most promising – with, of course, additional elements for precipitation hardening.

One fabrication process should be mentioned which seems promising – the technique of powder metallurgy, whose development we will sketch later as respects ceramic-metal composites. Powder metallurgy allows us to use metals of the highest melting points, which can hardly be alloyed otherwise. Furthermore, grain size is much more easily controlled than in cast, unforged parts. For example, this technique allows us to fabricate parts of molybdenum, a metal that melts at 4750° F., and has a high tensile strength at high temperatures of service. One difficulty is that it must be protected against oxidation, and this problem is only partly solved by coating the article with another metal which converts itself to a refractory oxide, or with a compound which is at once firmly adherent and protective.

Powder metallurgy has also fabricated porous pieces of refractory alloys which can be cooled in service by forcing a cooling gas through the piece.

CERAMICS AND CERMETS

In order further to increase the operating temperatures and efficiencies of jets and other engines, materials even more refractory mechanically and chemically than metallic alloys must be investigated. Work has been centered on ceramic products which, compared to alloys, have the advantage of not being subject to oxidation and being generally very stable chemically at high temperatures, even after prolonged exposure at 1800° F. In addition, they usually have low density (4 g. per cc., more or less) – a very interesting fact for pieces moving at high rotational speed such as rotor disks of turbines, thus diminishing the induced centrifugal forces. Their static tensile strength is maintained quite well at high temperatures.

Apparently, the most favorable product is alumina. A new ceramic product has recently been introduced by Stupakoff Ceramic and Mfg. Co. based on a silico-aluminate of lithium. Compositions can vary considerably, with accompanying variations of coefficient of thermal expansion from positive values to negative. These ceramics are quite resistant to thermal shock, whereas others are not.

The disadvantages of ceramics usually cited are their fragility when cold and poor resistance to the thermal shocks to which the pieces are exposed in service.

Materials which cannot properly be called ceramics but which have the same advantages are the metallic carbides and borides. The

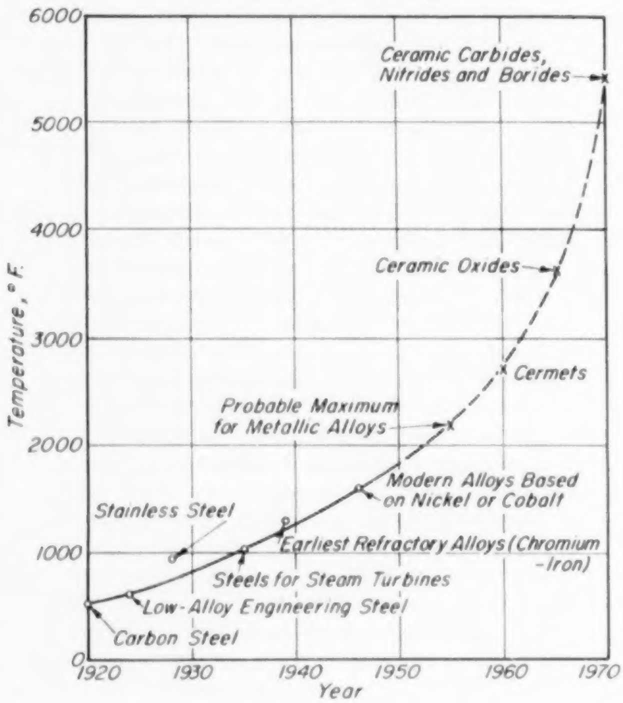
Cermets in Various Combinations

nitrides and silicides also are worthy of interest but have been less studied. Considerable experimentation with carbides of tantalum, columbium, titanium, and tungsten, and with borides of chromium, molybdenum, and titanium has been published in recent years. The most interesting formulations are no doubt still on the secret list.

In general, these materials have the same disadvantages as true ceramics. Parts made from them can only be fabricated by methods of powder metallurgy. (Mixing of the powders can be accelerated by ultrasonics.)

Due to the disadvantages of these materials when compacted without sensible amounts of binders, it has been proposed to combine the advantages of the two types of products – metallic alloys and ceramics – by means of powder metallurgy, thoroughly mixing the two products before sintering, much as the well-known tungsten carbide cutting tools are manufactured with cobalt binder. These composite solids are called "cermets", an artificial word derived from ceramic-metal. Resultant properties, such as resistance to thermal shock and to chemical corrosion, density, and tensile strength at high temperature, are intermediate between those of the constituents. However, the mixtures usually and notably improve the inadequacies of the two types of materials, as previously outlined.

Fig. 2 – Past Performance and Predicted Future Progress in High-Temperature Metals and Ceramics (J. H. Collins, Journal of Aeronautical Sciences, *April 1940)*



Many varied combinations have been studied; these will only be enumerated: *(a)* Alumina with iron or chromium; *(b)* oxide of beryllium or zirconium with cobalt, nickel, chromium, or copper; *(c)* chromium boride with nickel; *(d)* titanium carbide with nickel (well developed in America as "Kentanium") or with cobalt or molybdenum; *(e)* boron carbide with iron. Additions of tantalum or columbium carbide to titanium carbide and particularly to boron carbide seem to improve its resistance to oxidation.

In general, carbide cermets have a higher thermal conductivity and resist thermal shock better than oxide cermets, but the latter are more resistant to oxidation, as could be expected. Density of cermets is half or a third that of metallic alloys.

Studies are being actively pursued in various countries throughout the free world and have already yielded very promising results. Primary variables studied are the nature of the ceramic compound, the cementing metal and the proportions of the two. The best metal binder for a given ceramic compound is not necessarily the best with another.

Fabrication methods other than powder metallurgy are also being investigated – for example, the possibility that a porous ceramic body can be formed which can later be impregnated with melted metal. Likewise the metal and ceramic can be vaporized and, with the condensed product thus thoroughly mixed, proceed to a solid shape.

Ceramic products can also be used as protectors against oxidation for metals or materials with high tensile strength at high temperatures but subject to oxidation – for example, for parts made of unalloyed tungsten or molybdenum. Various processes have been tried; two will be mentioned particularly: The first consists in covering the part with borides or refractory silicides formed by direct reaction of an appropriate gas with the metal to be protected. The second consists in covering this part with a layer of an appropriate alloy which is later oxidized into a tight ceramic coating.

Figure 2 by J. H. Collins sketches the progress up to the present time in maximum temperature possible in service and, perhaps in a daring way, the progress to be anticipated in the coming two decades.

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Improved Manufacture of Large Alloy Steel Forgings

Most of the recent developments in the manufacture of heavy alloy steel forgings may be broadly classified under the following general headings:

1. Introduction of steel compositions not previously employed in such work, or only for a limited range of forgings of certain types.

2. Improvements in steel melting, ingot casting technique and ingot mold design.

3. Modifications in forging practice, sometimes coupled with intermediate heat treatments between successive forging stages.

4. Development of improved methods for the heat treatment of the completed forgings.

Obviously, it is impossible, in the space of one brief article, to deal with all postwar developments included within these four headings, and the author believes that his purpose will be best achieved by references to them in the course of a description of some major developments in forgings made from 3% chromium-molybdenum steel.

NEW STEEL COMPOSITIONS

In common with most important developments in steel manufacture, the utilization of 3% Cr-Mo steel for solid forgings of the largest types has proceeded slowly and methodically. The author's company has been turning to its use for some years, for the following reasons:

1. In the form of large ingots, this steel is characterized by less heavy segregation and less susceptibility to corner ghosts than other alloy steels capable of developing similar mechanical properties in large masses.

2. Forgings made from it are also less susceptible to serious troubles such as snowflakes ("hairline cracks", in Britain) than those from other alloy steels of comparable properties.

3. Partly on account of the characteristics dealt with in (1) above, it is the experience of the author's associates that the ratio of tangential and radial to longitudinal properties is superior in the 3% Cr-Mo steel to that of most other alloy steels after similar forging reduction.

4. The 3% Cr-Mo steel can be made in an acid openhearth furnace to a high standard of quality for such purposes as rotor forgings for large steam turbines and turbo-alternators.

Before and during World War II, 3% Cr-Mo steel (typical composition,* 0.25% C, 0.55% Mn, 0.25% Ni, 3.35% Cr, 0.55% Mo) had been used chiefly for various kinds of drop forgings, including aero-engine and motor vehicle crankshafts. For heavy forgings it was almost confined to large hollow vessels.

Extensive study in the research laboratory had shown, however, that this steel should be very suitable for large forgings of the solid type and, after an exhaustive investigation of the thermal transformation characteristics of the steel, together with its hot working properties, solid forgings of larger size were undertaken experimentally. Many of these forgings were sectioned, examined and tested in detail after various final heat treatments, with the result that predictions from research work were fully borne out. Consequently, full-scale manufacture was undertaken in collaboration with various users of large forgings. One of the first successful ones was a large disk forging for built-up turbine rotors; it proved to be much less susceptible to internal defects than similar forgings made from other alloy steels. The obvious next step was to manufacture one-piece rotors for steam turbines and alternators.

*This analysis is the same as the British En40B standard, intended for nitriding.

3% Cr-Mo Steel for Heavy Forgings

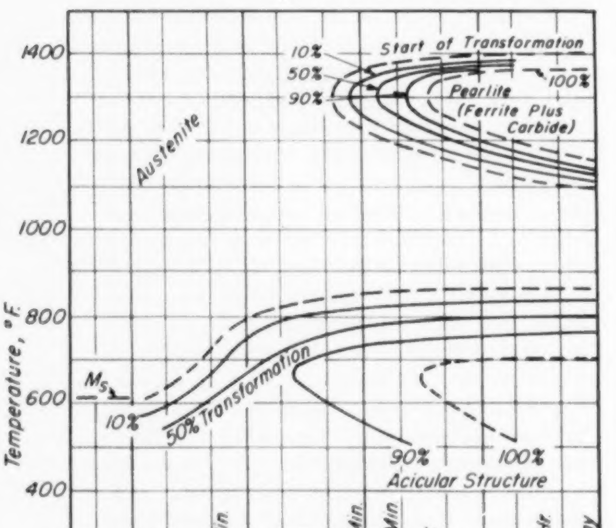
As an illustration of one of the most interesting characteristics of this steel, Fig. 1 shows a typical TTT-curve. Special attention is drawn to the comparative ease with which the steel has transformed in the "pearlite" range. About one hour is necessary for complete transformation at 1300° F. This advantage will be referred to again later in this article.

INGOT STAGE OF MANUFACTURE

Much attention has been paid to the effect of ingot size and shape, as well as to steel-making and casting temperatures and pouring speeds. Substitution of ingot molds of the round corrugated type for the older octagonal type has given greater freedom from corner segregates and a much wider range of pouring speeds. In these respects, some types of alloy steel previously used for large forgings have proved to be very critical, even with the best-designed ingot molds. On the other hand, this steel has a greater tendency to form skulls than nickel-bearing steels and, for this reason, higher pouring speeds are generally used.

At one time, some trouble was encountered with the 3% Cr-Mo steel in the form of non-metallic inclusions toward the lower end of the ingot, but this appears to have been overcome by a carefully controlled casting technique.

Fig. 1 – TTT-Curve for 3% Cr-Mo Steel Used for Massive Forged Rotors, Austenitized at 1650° F. Chemical composition: 0.25% C, 0.55% Mn, 0.25% Ni, 3.35% Cr, 0.55% Mo



Much attention has been paid to forging practice to avoid the unexpected and sometimes mysterious differences which have been found in finished forgings. Whereas the view was once held by many that a large amount of forging reduction was always beneficial, more thorough investigation has shown that the contrary is often true. In rotor forgings especially, which are tested tangentially and radially as well as longitudinally, there are definite advantages in keeping the forging reduction down to the minimum practicable.

Apart from the effect of forging reduction on the mechanical properties in tangential and radial directions, however, there is very strong evidence that heavy forging reduction, carried out at one and the same forging heat, increases the susceptibility of the forging to snowflakes or hairline cracks; these tend to be much influenced by the directionality brought about by the plastic flow of the metal, especially in the lower ranges of forging temperature.

PRECAUTIONS IN FORGING PRACTICE

For this reason there has been a tendency, which has become an established practice in the English Steel Corp.'s shops, to increase the number of forging heats to bring about a given reduction from ingot to the body diameter of a rotor forging, with the double purpose of insuring that plastic flow occurs at a high temperature, and that the directional effect of a given amount of reduction is partially removed by a subsequent reheating to the upper limits of the forging temperature range before any further forging is done.

In the largest forgings, an additional advantage appears to be gained by cooling the forging in between successive forging heats through the range of temperature corresponding to the austenite-pearlite transformation (assuming that the steel is one which can be fully transformed in this range) before a subsequent reheating for further reduction.

The thermal transformation characteristics of 3% Cr-Mo steel, as shown in Fig. 1, are particularly valuable in connection with the sequence of operations just described, since this steel can be transformed quite readily in the pearlite range, which is roughly between 1400 and 1300° F., and this type of treatment has been successful at the stages mentioned.

All manufacturers of large alloy steel rotor forgings must have encountered, at one time or

another, the elongated hairline crack confined to the region of large annular segregation. The multistage forging procedure with intermediate annealing has proved, to the author's satisfaction at least, to be very effective in preventing this type of defect which, in the past, has been even more difficult to overcome than the familiar type of snowflake which, in a fractured surface, appears to be almost circular in shape.

It may be interesting, in passing, to remark that, according to the experience of the author, there is little or no advantage to be gained from multistage forging which involves a series of upending, or upsetting, operations alternating with axial forging, though such a process has been favored by many manufacturers of large solid forgings, especially on the Continent.

HEAT TREATMENT ON COMPLETION OF FORGING

The proper design of the heat treatment cycle or cycles involved at this stage of manufacture has received much attention. It is one of the most critical stages in the manufacture of large alloy forgings in general, and of rotor forgings in particular, since these are some of the largest solid pieces which are made in comparatively highly alloyed steels. However well all the previous operations involved in steelmaking, casting and forging have been carried out, a forging can be either made or marred by the type of heat treatment applied immediately after forging. For this reason, many full-scale experiments have been carried out during recent years, with the primary object of establishing the most effective heat treatment for a particular type of steel and the secondary object of simplifying this heat treatment as much as is consistent with final success.

There is overwhelming evidence to show that the chief defects which are liable to afflict large solid forgings originate during or immediately after the heat treatment at this stage of manufacture. This statement does not, of course, apply to large internal defects such as clinks or forging bursts, but rather to the much more prevalent and insidious defects which may be broadly classified under the terms snowflake and hairline cracks. Based upon the theory that such defects were entirely caused by stresses due to volume changes associated with transformations and unsuitable rates of heating or (more especially) cooling, it was thought not very long ago that success could be achieved by a relatively simple heat treatment consisting of equalizing the forging at some temperature

Defects Originate in Heat Treatment

above the Ar transformation ranges, followed by controlled cooling through these ranges, and subsequent reheating to a temperature somewhat lower than the commencement of Ac_1.

Further experience with larger alloy steel forgings indicated that this simple treatment was ineffective, so the heat treatment cycle was modified by adding an intermediate "refining" treatment, consisting of heating the forging – after completion of the first transformation on cooling – to a temperature substantially above Ac_1, followed by controlled cooling through the Ar range and a final tempering as previously indicated. Even this more complicated cycle proved to be insufficient with still larger forgings, where success was often achieved by a repetition of the "refining" treatment just described, with the result that the heat treatment cycle consisted of four stages. With steels having a composition suitable for complete transformation in the austenite-pearlite range, the final tempering treatment was found to be unnecessary; with such steels, only three stages were required and many large forgings have been heat treated successfully in this way.

The exact role played by hydrogen in causing internal defects in large alloy steel forgings has received much attention by British metallurgists, and its influence, both on the formation of snowflakes or hairline cracks and on the mechanical properties of the finished forging, has been dealt with at length in the paper by Sykes, Burton and Gegg, published by the Iron and Steel Institute in June 1947. There still remain, however, a number of problems to be solved; not the least of these is the apparent influence of certain earlier stages of manufacture upon the success or otherwise of a particular series of heat treatments applied after completion of forging. Some of these are under investigation at the present time.

FINAL HEAT TREATMENT

It will be appreciated that, in all the stages of manufacture dealt with so far, no machining has been involved and the mass of steel has been maintained well above atmospheric temperature throughout the whole sequence of operations. Before final heat treatment to insure the desired properties in the final forging, machining is necessary in order to remove surface imperfections which might lead to serious trouble in any quenching operation. It has been found desirable also to subject the forging to

Table I – Mechanical Properties of Large Forgings for Turbo Generators

Location	Direction	Proportional Limit*	Maximum Stress	Elongation	Reduction of Area	Bend
	Low-Pressure Turbine Rotor, 54 In. Diameter, 117 In. Long†					
Bottom shaft end	Longitudinal	76,600	101,400	26.1%	67.0%	180°
Top shaft end	Longitudinal	79,300	104,300	26.0	67.8	180
Bottom rotor body	Transverse	76,000	100,700	24.2	57.3	180
Top rotor body	Transverse	78,200	102,800	24.2	53.9	180
Bottom rotor body	Radial	77,300	102,100	23.0	62.6	
Top rotor body	Radial	78,400	103,200	22.2	55.1	
Top of core	Longitudinal	80,600	105,000	25.0	61.5	
Middle of core	Longitudinal	82,700	96,800	19.3	45.6	
Bottom of core	Longitudinal	76,200	95,800	26.9	70.0	
	Rotor for Turbo-Alternator, 37 In. Diameter, 158 In. Long†					
Bottom shaft end	Longitudinal	83,400	106,100	24.9%	68.6%	180°
Top shaft end	Longitudinal	83,600	107,200	25.0	70.0	180
Top rotor body	Transverse	82,200	106,100	21.5	51.6	180
Top rotor body	Radial	81,900	105,600	20.0	49.7	180
Top of core	Longitudinal	86,100	110,800	22.3	61.1	

*At 0.5% strain. †Exclusive of shaft ends.

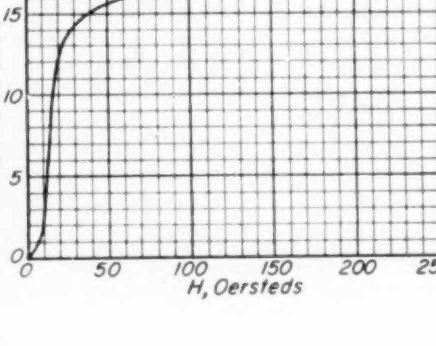
a thorough examination by ultrasonic methods at this stage of manufacture, since it would be useless to proceed further with a forging which already contained internal defects.

The author is fully aware of the various arguments which are often advanced against a final heat treatment consisting of oil hardening and tempering, and in favor of the alternative of air hardening and tempering, but a comparison of the mechanical properties and thermal stability of steam turbine rotors hardened by these processes has shown conclusively that the more rapid quenching is often most beneficial to the mechanical properties and not in the least detrimental from the point of view of thermal stability. Extensive experience with rotor forgings in 3% Cr-Mo steel, finally heat treated by oil hardening and tempering, has now been gained by English Steel Corp. over the past few years, and about 100 such forgings have been manufactured without the occurrence of a single case of cracking during heat treatment, or subsequent failure to behave satisfactorily in a thermal stability test. The rotors in question have ranged in body diameter from 24 to 55 in. at the time of heat treatment.

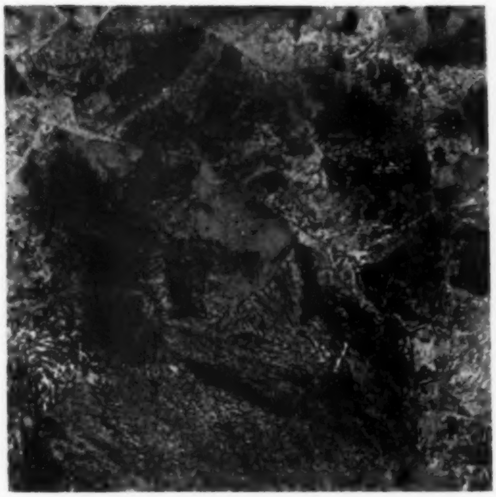
Probably our success in avoiding cracking is largely due to the employment of quenching periods which have been calculated beforehand so as to reduce the temperature at the center of the rotor body to the desired level below the transformation on cooling, as described by T. F. Russell in his paper, "Some Mathematical Considerations on the Heating and Cooling of Steel", in the *Journal* of the Iron and Steel Institute for 1936. At the end of this quenching period, forgings are invariably charged immediately into the tempering furnace and raised slowly and uniformly to the specified tempering temperature, where they are held long enough to insure complete thermal uniformity and subsequently cooled slowly to atmospheric temperature.

Preliminary mechanical tests from the shaft and body ends of the rotor are taken at this stage, and, if these indicate that the heat treatment has produced the desired results, the rotor is trepanned to provide core tests, which are the best possible indication that the heat treatment has been effective right to the center of the forging.

Fig. 2 – B-H Curve Showing Permeability of Rotor Forging After Final Heat Treatment



If the rotor forging is designed for a turbo-alternator, the next operation consists of a further stabilizing treatment, carried out at a temperature somewhat below that employed immediately after hardening. However, in the case of a steam turbine rotor which is subsequently to be "gashed",



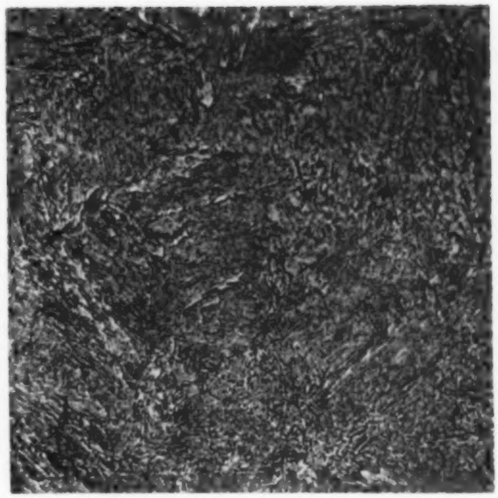


Fig. 3 (Left) – Microstructure at 500 × of Rotor Forging of 3% Cr-Mo Steel, 37 In. Diameter, 13 Ft. Long, After Isothermal Transformation at 1300° F. Brinell hardness 179. Pearlite with slight traces of ferrite network. (Right) – Tempered bainite in the same forging after final heat treatment. 500 ×. Brinell hardness 223

the machining is done after core testing but before the second stabilizing treatment.

The second tempering or stabilizing treatment serves the dual purpose of providing additional stress relief and of reducing the hydrogen content of the steel in the vicinity of the bore (which has already been trepanned for the core test previously mentioned). With steam turbine rotors of the "gashed" type, a considerable improvement in the properties of the forging as a whole is brought about by this second treatment, since hydrogen is able to escape freely from the additional surfaces exposed by the gashing operation. Many comparisons have been made between the elongation and reduction of area figures of forgings before and after this second tempering treatment and the improvement is sometimes quite surprising.

Results of tests taken from a large turbo-alternator and a large low-pressure steam turbine rotor respectively are shown in Table I. The steel in both forgings was a 3% Cr-Mo analysis, quite similar to the one quoted in the caption of Fig. 1, manufactured in the open-hearth furnace and finally heat treated in accordance with the schedule given above. Samples from the turbo-alternator rotor forging were given a permeability test to show the magnetization characteristics (Fig. 2), and it will be seen that these compare very favorably with the results obtained from previous steels employed for this purpose where the required mechanical properties are of the same order. Typical micrographs illustrating the structure after isothermal annealing and final heat treatment respectively also appear in Fig. 3.

Concluding Remarks – Developments under the headings stated at the beginning have been discussed with reference to rotor forgings in 3% Cr-Mo steel. It will be appreciated that much of this development also applies to other types of forgings and to other types of steel, especially in the remarks dealing with modifications to forging procedure and heat treatment immediately after completion of forging. With alloy steel forgings especially, most of these developments are essentially metallurgical in character. It is the author's view that, as the size of forgings still further increases – which seems almost inevitable – the metallurgical problems will continue to prove the most difficult. Many forging plants already in existence are capable of dealing with alloy steel forgings still larger than those which have been made up to this date, and other larger units of plant are either planned or in the course of construction which would enable this size to be extended further.

In the production of satisfactory ingots of the necessary size, however, and perhaps still more in the development of the most effective and economical heat treatments to be employed at various stages of manufacture, there is still a large and most fascinating field for further study. Research is also needed in the selection and improvement of steel compositions which promise some simplification in ingot-making and heat treating techniques.

By HANS VON HOFE, Scientific Aide
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Cologne, Germany

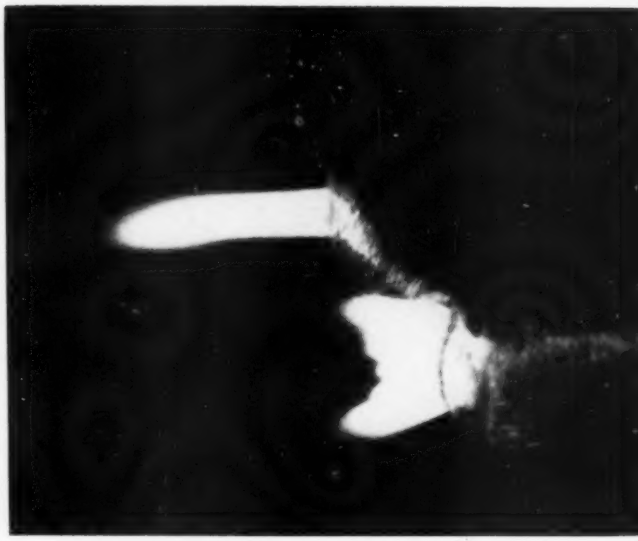


Fig. 1 – Two-Flame Slit Torch Has Fan-Like Flame for Preheating the Joint Ahead of the Welding Flame

Postwar Trends in German Welding Technology

A COMPREHENSIVE picture of the development of welding technology in Europe since the end of World War II is hardly possible, since the exchange of knowledge between individual countries is still so obstructed. Economic divergencies between European states are responsible for completely different approaches to welding problems and therefore lead to completely different solutions. An attempt can only be made to give a general insight into the German situation during the postwar period. The author was privileged to be a member of the Study Group which toured the eastern United States prior to the First World Metallurgical Congress in Detroit in 1951 and contrasts to American practice will be noted.

After the unfortunate partition of the German Reich, the Federal Republic of Germany with an area of 87,000 sq.mi. and a population of 43 million is the seventh largest state in Europe with the third greatest population. To compare this to the American situation, one must imagine that all the population of New England, New Jersey, Maryland and the District of Columbia were moved in on the present inhabitants of New York and Pennsylvania, and that these two states were then separated from their surroundings by national boundaries. Remember also that in 1946 the industry of this land was paralyzed by the war, the currency was completely disorganized, and the population was constantly swelled by the influx from the East. This situation would scarcely have been overcome without generous help from the U.S.A. Reconstruction is now quite evident. However, in the last few years these conditions existing in Germany have had a strong influence on all our industry, including that of welding and allied processes.

German industry has an honorable position in the development of the welding processes now used throughout the civilized world. The older and well-established methods are well perfected. Of recent years, foreign innovations are attentively studied, but they are applied only after meticulous testing under the individual conditions to be met. This rule, which is frequently unintelligible to a foreign engineer, is necessary because unsafe investments with scanty capital must be avoided. In addition, the proportion accounted for by manual welding in Germany is still about 90%, while in the U.S.A., this fraction amounts to 75% or less. Since hand work is cheaper in Germany (the average hourly wage of skilled workers is 60¢ as compared to about \$2.00 in the U.S.A.) and an adequate supply of experienced welders is available, manufacture in small lots or even

individual pieces predominates over mass production, and automatic welding processes have but limited interest.

Therefore, one is inclined to place a greater significance on semi-automatic processes. These facts also account for the circumstance that gas welding and automatic gas welding are much more widely used than in other countries. Although its merits are known to Germans, shielded-arc welding under argon (on a purely cost basis) can compete with gas welding only in special cases, such as in the welding of corrosion resistant steels.

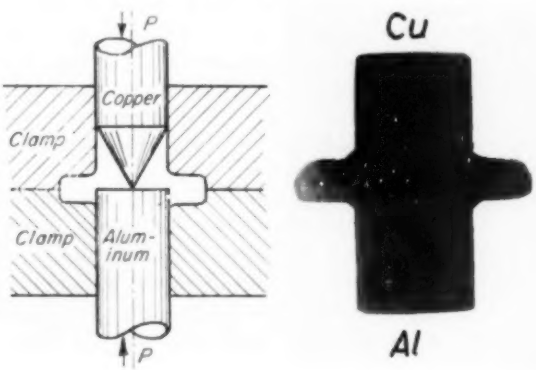
EQUIPMENT AND PROCESSES

In a brief review such as this it is impossible to describe in detail some new equipment which appears to have unusual merit. Only the most cursory mention can be made; a more complete account must be reserved for a subsequent article.

Manual Welding – The main obstacle to manual gas welding is its lower melting capacity compared to arc welding. This can be corrected if one employs double welding, or if one uses one of the new two-flame torches for thicker plates. In double welding, two welders work simultaneously, one on each side of the plate. Due to the accumulation of heat at the base of the weld, one can work with smaller torches, and less gas is consumed because of the increased welding speed.

The modern two-flame slit torch shown in Fig. 1 possesses a dovetailed preheating flame which heats the plate edges at the optimum distance from the welding flame. The welding flame then has only the hot base material and the rod to melt. Compared to normal single-flame welding, approximately 20% of the gas is saved because of the higher welding speed, and despite the higher hourly consumption. This equipment has proved especially good for autogenous joint welding and for building up worn surfaces, and it is being extensively utilized in Germany.

Fig. 2 – Aluminum Rod and Pointed Copper Rod Are Heated in Clamp and Forced Together Endwise, Resulting in Tough, High-Conductivity Joint Shown (Sectioned) at Right



Much attention has been given to special coatings for arc welding, either manual or semi-automatic. Some coatings produce protective gases, some contain iron or alloy powder, and some are placed on the bare wire as it is fed through an automatic welding head.

Stud welding received much attention immediately after its discovery. However, utilization is strongly inhibited by the price of imported studs which is extraordinarily high. This would be corrected if a license could be granted to a German firm.

Cold Welding (Forge Welding) – Due to the lack of copper, we are forced to use aluminum for electrical power transmission lines. Dependable joints between the existing copper lines and adjoining aluminum lines cause great difficulty. These joints must possess *(a)* the necessary strength, *(b)* high electrical conductivity and *(c)* high corrosion resistance, despite the wide separation of copper and aluminum in the electrochemical series. Toughness requires a minimum of the brittle intermetallic compound Al_2Cu at the joint. It seemed possible to meet these conditions, since copper-plated aluminum sheet suitable for deep drawn articles had been made in Germany for some years. Quite suitable butt joints between heavy-gage aluminum and copper wire and bars are now made as follows: The aluminum rod is cut, perpendicular to its axis. The copper rod is pointed to a conical shape if round, or wedge shape if rectangular. The two pieces are put in a clamp and brought to 1125° F. – around 100° F. below the melting point of the lower-melting material. They are then forced together under pressure inside the clamp, whereby the stiffer copper point is forced somewhat into the softened aluminum metal. A certain amount of sidewise flow occurs, filling an annular slot in the clamp, and producing a joint shown (sectioned) at the right of Fig. 2. The excess is then trimmed off. At least the strength of aluminum is obtained in such a weldment; joints can be bent more than 90° without failing, and the electrical conductivity is practically unimpaired. Corrosive attack can occur only at the surface, if moisture reaches this joint through a plastic cover.

New Ideas in Welded Structures

In passing, it may be mentioned that true "cold welding" of steel, even at temperatures of liquid air, has been done experimentally, although no industrial application of the process is known to the writer. Evidently, clean surfaces, if pressed closely enough together to come within the range of atomic surfaces, will join into a solid.

WELDED CONSTRUCTION

For years we have recognized that essential savings can be made by welding if carried out properly. For this it is necessary that the designer know the welding methods and their significant use. Through lectures, literature and study courses, they have been specially trained toward this end – a matter facilitated by the fact that a large number of designers were forced out of aircraft construction and had to find new work in other fields, wherein the special methods of light construction have been successfully put into use.

At all events, it must be borne in mind that there is a nice balance between the total cost of a weldment and the total cost of an equivalent article made by forging, casting, or a riveted assemblage. Additional costs of design – especially of a single piece, or of a few duplicates – must not amount to more than the materials which are saved by welded lightweight fabrication.

Some especially striking examples of recent welded structures should illustrate the best designs. The outstanding characteristics of welding are taken advantage of in the construction of steam turbines. The rotors are welded together out of individual forged rings, six in number, and two end disks. Formerly these were machined from a large forging. In addition to great savings in machining time, savings are made in weight. (Welds of these turbine rotors are tested by ultrasonic methods.)

Fig. 3 – Erection of Welded Girders in Rhine Bridge at Düsseldorf. Members weighing up to 60 net tons were shop welded

As an example of machine tool construction a lathe bed may be cited. It is formed much like a box girder, set on two boxes at the ends. The individual components are shaped separately and welded together. The ways are also welded on the bed and then flame hardened and ground to correct alignment. The advantage of welded construction here lies less in the saving of material than in the pattern costs and the long delays elapsing until the cast body is finished. These advantages are especially important for special machines made individually as compared to mass production.

Restoration of destroyed bridges was one of the most pressing tasks of the postwar period. The Rhine crossing at Düsseldorf with its spans of 340, 675 and 340 ft., and its breadth of 100 ft., is the largest welded frame bridge in the world. The individual members, up to weights of 60 tons, were welded in the shop; the joints were riveted. A special steel with outstanding weldability enabled this to be done with an over-all weight of just under 7000 net tons. Erection view of one of the cantilevered spans is shown in Fig. 3.

The walking crane (Fig. 4) for the Bremen dockyards shows some completely new ideas. The gantries are 33 ft. high and a load of three tons can be lifted 120 ft. above the deck at a radius of 65 ft. The legs are rectangular boxlike sections made of ¼-in. steel plate, as determined by experiments with plastic models wherein compressive stresses were found to set up the critical loads. Compared to the usual method of construction, 30% was saved in the weight of the gantry. The crane jib is erected as a tube-welded framework; as compared to the normal framework it has about 40% less weight. In addition to these advantages the neatness of form should also be emphasized.

MANAGEMENT OF WORK

Because of our different manner of training welders and our production conditions, great differences exist in German manufacturing as compared to the U.S.A. Completely detailed drawings and shop instructions are not universally employed; the foundation for the prep-

aration and execution of welding often is left to the welder on the basis of his experience to select the correct fastening, welding procedure and filler material. One prerequisite is still missing for the uniform application of engineering drawings – namely, the standardization of symbols. Some use is made of the American standards.

For reasons already mentioned, welding machines are not used frequently, although the saving of labor and simultaneous improvement in quality of weldments is recognized. German practice has been to avoid the cost of procuring the machines and to depend on the ability of the welder, who can usually produce welds of adequate quality even on perpendicular walls and overhead work.

Post-treatment of welds is specified in such fields of manufacturing as tank construction, pipe lines, pressure vessel and steam boiler construction. On the basis of our own experience and recent American examples, more and more "stress-relieving" is done instead of the hitherto commonly used normalizing process. Before this practice is admissible, considerable research must be carried out to prove its efficiency and safety.

TESTING AND ACCEPTANCE OF WELDS

Since the beginning much attention has been given in Germany to the methods necessary to guarantee uniformity in welds and safety of welded construction. Performance, inspection and safety codes of semi-legal status have been adopted after agreement among various factors in the industry. This has extended to requirements for safe practices in the shops themselves which handle compressed oxygen and acetylene gas. Standards for compressed gas cylinders have specified particulars of design, materials of construction, production methods and acceptance testing. Connections have also been standardized in such a way that regulators, fittings and hose for oxygen (for example) will not fit on cylinders containing another gas. The codes governing acetylene generation and distribution are especially detailed.

Common to the codes governing steel buildings and bridges, pipe lines, tanks and pressure vessels are provisions that the shop and field welding may be carried out only by qualified welders who are constantly under the supervision of a welding engineer. Furthermore, the welding engineer is not only responsible for the execution of the welding but also for the stress calculations and the design. He is obliged to

assure himself continuously of the reliability of his welders and to record all details of his examination during the work – a responsibility that leads to careful checking.

Welders must be re-examined before they may be employed on work governed by these codes if they have not done satisfactory work of the same nature within the last six months. All concerned have agreed that such rigid provisions have had much to do with the general success and freedom from failure which the German welding industry has enjoyed.

It is fundamental to differentiate between the testing of the welder's ability and the continuous control of the quality of his work. Every special welder (pipe, boiler and structural steel welder), after completing a training period of several weeks, is examined by State examiners according to stipulated instructions. If he passes this examination he is permitted to be employed on work coming under the codes. His work is then continuously checked through short tests and random samples from commercial weldments.

Such continuous testing is expensive both in time and material. An interesting proposal has been made by Kautz for minimizing these costs through the use of plate samples shown in Fig. 5.

Fig. 4 – Walking Crane, 3-Ton Capacity, for Bremen Docks, Completely Welded, Saved One Third the Weight of Prewar Prototype

Training Welders

After welding, holes of indicated size are bored along the center of the seam, and four test pieces cut by oxyacetylene flame, two being tested in tension and two in bending. Fracture takes place in the weld, which has not been influenced by the heat of the gas cutting.

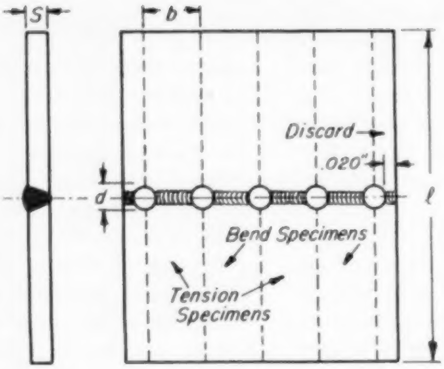


Fig. 5 – Routine Test Piece Verifying Welder's Performance (Proposed by Kautz)

S	b	d	l
Up to 0.40 in.	0.79 in.	0.40	6 in.
0.40 to 0.80	1.38	0.60	7¾
0.80 to 1.40	1.77	0.79	10

X-ray tests are extensively carried out for acceptance of welded structural members. It is generally recognized in Germany that the automatic X-ray method has resulted in an increase in the quality of welds, since the welders are thereby able to detect their defects with certainty. While adequate knowledge and unambiguous data are at hand concerning the ability of X-rays to detect defects, such information is still lacking for ultrasonic testing. Since pipe weldments in an extremely high-pressure installation have been inspected by other means and it was found that the ultrasonic method can detect defects at least equally well, and since the savings in time and money are significant, it can be accepted that this new testing method will also be approved by the authoritative bodies.

GERMAN ASSOCIATION FOR WELDING TECHNOLOGY

Founded in 1947, the German Association for Welding Technology embraces eight national associations having some 5200 members organized in 63 local groups. Membership includes individuals and firms, governmental representatives, and others from educational institutes. Extensive investigations are supervised by 27 working committees. Local associations hold regular meetings throughout the winter months, thus being similar in activities to the Chapters of the . An annual convention and exposition is held – thus also paralleling the . A monthly technical journal *Schweissen und Schneiden* (Welding and Cutting) is sent free to members.

One of the principal responsibilities of the German association is the proper training of the welder and education of the welding engineer. This is centered in six institutions and supplemented by extension courses at 71 localities. While fees are charged, the courses are subsidized by industry.

Typical training for a welder includes graduation from primary school (at about 14 years of age), at least four years of general work in the mechanical or construction industry, a 300-hr. course about equally divided between elementary lectures for apprentices, training in fundamentals, and welding practice. (Some of these are available in evening courses.) He then resumes work in a welding shop until he is at least 21 years of age, then attends "finishing school" for a 132-hr. course, in which he pays special attention to sound practices for pipe welding, sheet metal welding, and similar specialties. He must then pass a final examination to be accredited as a "trained welder".

Welding engineers must be graduates of primary and junior high schools; at the age of 17 they take the 300-hr. course described above for welders, after which they work in industry for at least 18 months before entering a technical college or institute. Graduating therefrom and after at least three years of practice in a chosen branch of industry, they enter an advanced 192-hr. course leading to the degree of Welding Engineer. This can hardly be achieved at an age less than 25. In his field the professional welding engineer is alone fully responsible for correct welded construction, the proper execution by the welder, and orderly acceptance of the finished structure.

Welding instructors are chosen from engineers who have had many years of experience in plant or field, and have been uniformly successful in handling design and operating problems, as well as being skilled operators of welding equipment.

An echelon of professional welding engineers is available, who cooperate as closely as possible with the plants of their districts, and by demonstrations, committee work, and schools in the plants help overcome the difficulties which occur. This organization is responsible for the fact that autogenous techniques are used to a proportionately greater extent in Germany than in other countries.

INFLUENCE ON OTHER GERMAN INDUSTRY

Until 1930 welding technology was not given any more real attention than in other countries. At that time the construction of welded naval vessels provided the impetus for the rapid development of welding technology, and for a long time it may

(Continued on p. 168)

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

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COLUMBIUM and TANTALUM

Strategic Combination for Imparting Strength and Stability to High-Temperature Metals

Gas turbines for jet-aircraft engines, and for other similar engines being developed for marine and railway transportation, have greatly increased the demand for high-temperature metals. The present most satisfactory metals are either iron-base, nickel-base, or cobalt-base. They are used in the form of castings and hot-worked products, such as forgings, bars, and sheets.

Many of these special metals contain columbium because of its beneficial effect on high-temperature strength in both cast and wrought products. Investigations have shown that columbium is one of the key alloys for imparting high-temperature strength and stability in metals suitable for operating temperatures up to 1500 deg. F. and above.

Need for New Alloy

Originally, a ferrocolumbium alloy containing approximately 55 per cent columbium and 5 per cent tantalum was employed in the production of many of these high-temperature metals. However, with the increased use of high-temperature metals and columbium-bearing 18-8 stainless steels, the demand for columbium exceeded its availability.

ELECTROMET's Research Laboratories began investigations to ascertain whether an alloy containing more tantalum and less columbium would be equally satisfactory for producing the high-temperature metals. Columbium and tantalum alone, as well as combination alloys of columbium plus tantalum, were tested.

Results of Tests

The alloy N-155 was selected for tests. It is an iron-base alloy with the following approximate analysis:

Chromium	20 per cent
Nickel	20 per cent
Cobalt	20 per cent
Tungsten	3 per cent
Molybdenum	2 per cent
Columbium	1 per cent
Nitrogen	0.15 per cent
Carbon	max. 0.35 per cent

The data in the table below describe the mechanical properties, at room temperature, of this low-carbon N-155 alloy modified with columbium and tantalum alone, and with combinations of columbium plus tantalum. The metal modified with columbium has good strength and high ductility at room temperature. These same good properties are obtained when tantalum, or tantalum plus columbium, is substituted for the columbium.

Stress-to-rupture tests were also conducted on these same modified low-carbon N-155 alloys at 1350 and 1500 deg. F. The data show (see table) that when the columbium is replaced with a mixture of columbium plus tantalum, the strength of the metal remains substantially unaffected at 1350 and 1500 deg. F. Also, when all of the columbium is replaced with tantalum, the strength of the metal at 1500 deg. F. is equivalent to that obtained with columbium. Hence, from the standpoint of high-temperature strength, columbium and tantalum can be used interchangeably, or in combination.

Properties of Modified N-155 Alloys Compared*

Typical Analysis, %**	With Columbium	With Columbium and Tantalum		With Tantalum
Columbium	1.13	0.58	0.49	....
Tantalum	0.08	0.64	0.53	1.47
Carbon	0.12	0.13	0.13	0.12
Nitrogen	0.13	0.14	0.14	0.14
At Room Temperature				
Tensile Strength, psi	119,000	123,200	117,500	122,100
Yield Strength, psi	56,700	59,500	52,000	59,100
Elongation in 2 in., %	52	47	57	54
Reduction of Area, %	69	65	69	56
At 1350 deg. F.				
Stress to Cause Rupture, psi				
In 100 hr.	31,000	34,000	33,500	....
In 1000 hr.	23,000	25,000	23,000	....
At 1500 deg. F.				
Stress to Cause Rupture, psi				
In 100 hr.	20,000	20,000	20,500	20,000
In 1000 hr.	15,000	14,000	15,500	15,000

* Tests made on standard samples from one-inch round bars, water-quenched from 2250 deg. Fahrenheit.
** Composition of the base alloy is given in the text.

Help to Industry

ELECTROMET has developed an alloy containing approximately 20 per cent tantalum and 40 per cent columbium for use in high-temperature metals and stainless steels. It is known as ELECTROMET ferrotantalum-columbium.

Industrial experience with this comparatively new alloy has confirmed the favorable results of the experimental work. The alloy has already aided considerably in augmenting the supply of columbium alloys, since it is just as effective as ELECTROMET ferrocolumbium, with 50 to 60 per cent columbium, for giving strength at high temperatures.

Furthermore, the new alloy is now preferred because of its greater availability. It should be added to a thoroughly deoxidized metal bath to obtain the best results. A recovery of about 90 per cent for the columbium and 80 per cent for the tantalum may be expected.

For further information regarding alloys for high-temperature metals, write to the nearest ELECTROMET office: in Birmingham, Chicago, Cleveland, Detroit, Houston, Los Angeles, New York, Pittsburgh, or San Francisco. In Canada: Welland, Ontario.

Correspondence

Utility of Strauss Test

SCHENECTADY, N. Y.

The amount of data on the corrosion of austenitic stainless steels in $CuSO_4$-H_2SO_4 solutions is relatively scarce in view of its importance as one of the popular tests for the detection of sensitivity to intergranular corrosion. The success of this type of corrodent, used in what is generally known as the Strauss test, depends on the passivating effect of the concentration of $CuSO_4$. A popular plot by J. H. G. Monypenny often cited to illustrate this behavior is mislabeled both in the *Metals Handbook* (Fig. 2, p. 559) and the *Corrosion Handbook* (Fig. 1, p. 152) as data obtained on testing 18 Cr – 8 Ni stainless steel. These curves were obtained by Monypenny after corrosion testing for 24 hr. a martensitic stainless steel having 0.30% C and 12.6% Cr in hardened and tempered condition.

Monypenny does cite data in his book *Stainless Iron and Steel* on the corrosion of austenitic stainless steel in $CuSO_4$-H_2SO_4 solutions (second edition, p. 336; third edition, Vol. 1, p. 305). He tested "Anka" steel (0.12% C, 14.9% Cr, 10.7% Ni) at various temperatures in a solution of 100 g. per l. of H_2SO_4 with $CuSO_4$ varying from 0 to 0.5 g. per l. At 20° C. strong passivity occurred for additions between 0.05 and 0.10 g. per l. of $CuSO_4 \cdot 5H_2O$. At boiling temperature, at which the Strauss test is usually conducted, strong passivity was found between 0.4 and 0.5 g. per l. of $CuSO_4 \cdot 5H_2O$. It is of interest that B. Strauss himself mentioned Monypenny's work as suggesting the utility of $CuSO_4$-H_2SO_4 solutions for the corrosion testing of stainless steel.

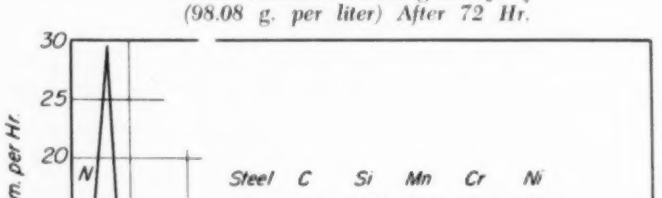
Confirming data on the effect of $CuSO_4$ on boiling H_2SO_4 solutions are given by E. C. Rollason (*Journal*, Iron and Steel Institute, Vol. 127, No. 1, 1933, p. 396) using three compositions of unmodified Cr-Ni austenitic steels bracketing the 18-8 range. These data also show the onset of a strong passivating action between 0.3 and 0.5 g. per l. of $CuSO_4$. A plot of Rollason's data (Fig. 1) also illustrates the general effect of increasing chromium contents. The high silicon of his steel "S" does not make the data strictly comparable.

Although both Monypenny and Rollason's data show no practical difference in corrosion rates for $CuSO_4 \cdot 5H_2O$ contents greater than 1 g. per l., S. J. Rosenberg and J. H. Darr (*Transactions*, Vol. 41, 1949, p. 1267) specifically discarded their use of 13 g. $CuSO_4 \cdot 5H_2O$, 47 ml. H_2SO_4 per liter of solution because of general attack excessive for their purposes. They found that a solution of 100 g. $CuSO_4 \cdot 5H_2O$, 100 ml. H_2SO_4, 900 ml. H_2O was sufficiently passivating so that slight intergranular attack would not be overshadowed by general attack.

Significantly, W. O. Binder and C. M. Brown, as well as M. H. Brown, W. B. DeLong and R. W. Myers in their papers reported in the A.S.T.M. "Symposium on Evaluation Tests for Stainless Steels", Special Technical Publication No. 93, utilized $CuSO_4$-H_2SO_4 solutions with these same proportions of salt and acid. An early Air Ministry Specification (British) used in 1933 and adapted from W. H. Hatfield's work employed a sensitivity-detecting solution containing 111 g. $CuSO_4$ per liter of $2N\,H_2SO_4$.

(Continued on p. 138)

Fig. 1 – Influence of $CuSO_4$ on Corrosion Rate of Annealed Cr-Ni Austenitic Stainless in Boiling $2N\,H_2SO_4$ (98.08 g. per liter) After 72 Hr.



Correspondence

(Continued from p. 136)

Since testing periods longer than 72 hr. are finding more utility for Strauss test sensitivity detection in laboratory investigations, the point as to whether sufficient passivity is obtained with $CuSO_4 \cdot 5H_2O$ contents less than approximately 100 g. per l. becomes important. The experimental answer to this question may hasten the time for adoption of one Strauss test solution which will fill most of the needs of industry and research laboratory and so lead to standardization, with all of its advantages.

L. H. Satz
Metallurgical Engineer
General Engineering Laboratory
General Electric Co.

Scandinavian Metalworking Plants

Los Angeles

My visit to the Scandinavian countries presented a most interesting opportunity to compare the world's newest and most rapidly expanding area of metals production and metalworking – western United States – with one of the oldest and most stable centers of the metals industries.

As a member of the six-man National Management Council team, arranged by ECA, I was in a most excellent position to study the metalworking field in Sweden, Norway, and Denmark and to learn first-hand some of the problems which the industry there faces on numerous levels, many of which do not exist in our plants because of the great difference in our basic social and economic conditions.

Some of the metal fabricating shops which we visited were established as long ago as 1650, and many of the machine shops, foundries, and plants, in the old-world tradition-bound atmosphere in which they operate, have made relatively few changes in the last 300 years.

Our team was sponsored by ECA to bring to the countries visited – Sweden, Denmark, and Norway, all of them under the Marshall plan – the American "know-how" so that they in turn might have greater productivity, higher wages, more profits – with resulting improved living conditions. Morris B. Pendleton, president of Plomb Tool Co., Los Angeles, was the team leader.

As for the total production of the metalworking industries of the three Scandinavian nations, its volume would have the same ratio in comparison with ours as the output of one of our experimental machine shops bears to the factory which it serves.

It seems to be a matter of outlook. Here in the West distance means nothing. We live in a big country and pride ourselves in "thinking big". In contrast, those in three northern European countries, small in size and in population, for centuries have been accustomed to thinking within narrow boundaries.

Denmark, for example, is approximately the same size and population as Los Angeles county. Its metalworking industry cannot extend its selling beyond the country's boundaries without encountering tariffs and restrictions and all the headaches of export trade. But the whole of the United States is within the selling field of Los Angeles plants.

Limited outlook does not mean that these Scandinavian countries have not played an important part in the development of metalworking technology. Sweden in particular has long been noted for the fine steels it produces as well as the contributions of its technicians in the fields of military ordnance. Engineers in Norway and Denmark were largely responsible for the development of the diesel engine.

It is interesting to compare with our ways the various phases of the metalworking industry. First, the matter of high production. With rare exceptions, there is little realization of its requirements.

The making of dies and molds is an example. In this country diemakers concentrate their attention on the necessary finish for the working surfaces. In the Scandinavian plants all surfaces receive the same treatment, with the result that their dies and molds are beautiful to behold, but the time spent on the nonworking surfaces serves no useful purpose and slows production.

The lack of efficient plant arrangement is generally evident. Nonrelated plant activities exist side by side, and often the company's different products have nothing in common and require totally different production facilities. One plant in Copenhagen makes diesel engines and washing machines within 25 ft. of each other – and also operates a jobbing foundry in the same location.

At Jönköpping, Sweden, a manufacturer turns out sewing machines, kitchen utensils, bicycles, motorcycles, sporting rifles, and shotguns with the same die and machine shop facilities.

Since every company does everything necessary for its own products, specialization in the processing field as we know it here in the West is very rare. For instance, we saw no jobbing heat treating firms, since apparently

(Continued on p. 140)

Correspondence

(Continued from p. 138)

each firm that requires such a process has its own equipment. The same is true of slitting and pickling.

There are exceptions, where plant modernization has been attempted. However, in most cases it is not consistent. One 300-year-old firm was still using practically its original methods of making its line of cutlery and hand tools, yet operated a wholesaling hardware business in a modern warehouse and sales office.

The SKF plant in Katrineholm, Sweden, is, however, outstanding as an efficient up-to-date manufacturing operation, with its large, well-equipped factory and modern machinery, much of it American, I noticed – and compares favorably with our best here. Eskilstuna, Sweden, has a tractor plant whose production line is organized and operated in accordance with our modern techniques. It's one of the few – and it is *small*.

Size, of course, is one of their peculiar production bottlenecks. It extends down to the production of the metals. However, a new steel mill just constructed in west central Norway is, or soon will be, producing at the rate of 250,000 tons annually, thereby quadrupling present production.

Another bottleneck is inadequate rail transportation facilities. The largest freight car I saw had a maximum load capacity of 10,000 lb. of steel. This is probably due to their traditionally greater reliance on waterborne freight.

Again, there is the matter of industrial relations. Old established customs and social thinking influence the attitude of both labor and management. Labor is not producing anywhere near capacity, yet piece rates are in general use. There seems to be self-imposed output ceilings on the part of the workers, which appear to be an outgrowth of the collective security principle. This, of course, lessens initiative ambition.

Very little use has been made of such production-building devices as time studies and incentive plans. Both management and the labor groups are familiar with these techniques and appear to favor them, but they do not cooperate in making them an effective tool for increasing output. Rather, there seems to be a tendency on the part of management to make downward adjustments in incentive pay as production increases, with the result that labor has established arbitrary ceilings. Also qualified industrial engineers, such as are common in this country, are noticeably scarce.

The field of public relations and selling seems to be equally poorly developed. The absence of aggressive selling in the countries we visited is probably the result of a seller's market and of cartels. These cartels and employer federation agreements, condoned by the governments, hold up consumer prices and keep the marginal producer in business, even though the stronger and more efficient producer might otherwise capture his markets – and his emloyees – as well as selling at a lower price.

What of tomorrow? The Scandinavians are self-reliant and hardworking. Their natural desire is to excel. There is good reason to believe that as the modern techniques of U. S. production are effectively presented to them, they will be quick in adopting the measures most appropriate to their system. ECA aid is no longer used by Sweden and soon Norway and Denmark should also be able to depend on their own resources.

F. J. Robbins
President
Sierra Drawn Steel Corp.

First Latin-American Metallurgical Congress

Pittsburgh

The first Latin-American Metallurgical Congress was held between Oct. 13 and Nov. 5, 1952, in Bogota, Colombia. Sponsored by the Economic Commission for Latin-American Technical Assistance Administration, the Congress was a project of the United Nations, and was headed by Mr. Bruno Leuscher, executive director of the working group on iron and steel industry in Latin America.

The purpose of this Congress was:

1. To discuss collected technical information to determine the economic possibilities of developing steel industries to serve national requirements or, as an alternate, to limited developments to serve local markets within the countries of Latin America.
2. To assist the present steel industry in Latin America by interchange of experiences in various fields of metallurgy, especially steelmaking.
3. To better understand the problems confronting the countries in producing and marketing their products.

The Congress was assured immediate success by an enthusiastic response of its visitors who had arrived from all over the world. The impression one gained from the meeting was that the Latin Americans are aware of their great unexplored natural resources and are on the threshold of developing their basic industries.

Many experts in the ferrous indus-

(Continued on p. 142)

Correspondence

(*Continued from p. 141*)

try presented papers (since the Congress was a United Nations' project, the official language was English) on iron ore reduction, steelmaking and finishing, with special attention being given to European and Latin American practices. This emphasis was made because many Latin-American countries experience a severe shortage of scrap metal which prevents them from adopting North American steelmaking practices; therefore information was sought from European experts who, at times, are faced with similar problems.

It was especially significant that the meeting was held in Bogota, since in the near future Colombia will have its own integrated steel plant. At present, the country has only one small steel plant, Siderurgica de Medellin, located in the industrial city of Medellin. The new plant, Siderurgica de Paz de Rio, will be completed late in 1953; this will give South America its third complete steel plant, the others being Volta Redonda in Brazil and Huachipato in Chile.

Located at Belencito, 138 miles northeast of Bogota, the plant's pig iron capacity will be about 180,000 tons annually and its steelmaking facilities will consist of one 500-ton blast furnace, three Thomas converters, one electric furnace, and a coking plant. Principal raw materials are found within 35 miles of the plant site.

KURT SCHLESINGER
Sales Engineer
United Engineering & Foundry Co.

Hardness Measurements of Cemented Carbides

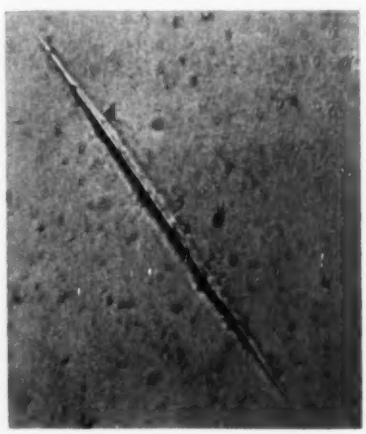
LONDON, ENGLAND

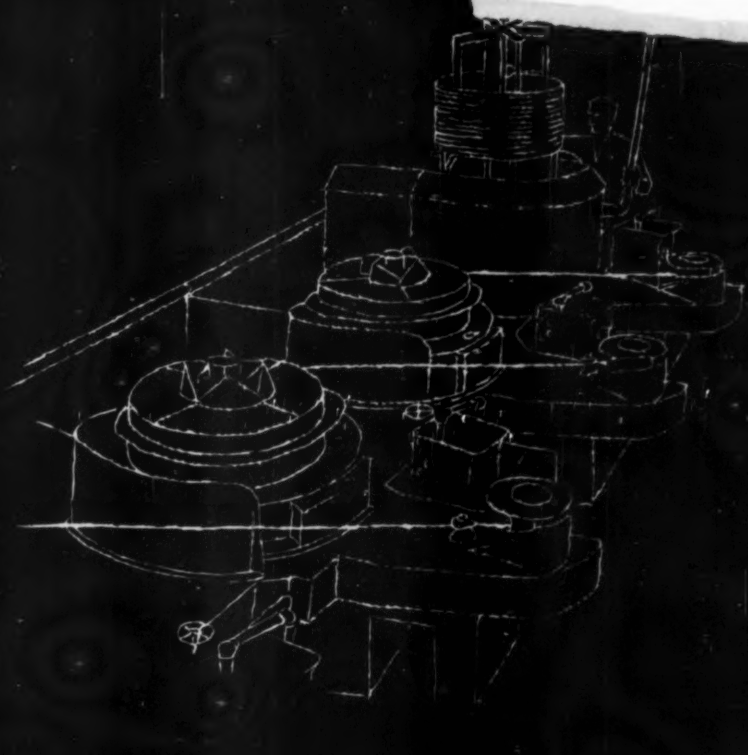
The abstract "Testing Cemented Carbides" (*Metal Progress* for July 1952, p. 124) contains a statement that hardness tests for Rockwell C cannot be used owing to considerable diamond breakage and instead the Rockwell A test is recommended. Frequently, the Vickers diamond pyramid is also used for determining hardness of sintered carbides, but here again the same difficulty is met.

As a result of similar experience with diamond breakage, some years ago I developed hardness testing diamonds which have a cutting edge instead of a point. The simplest geometrical form of such an indenter for testing flat surfaces is the double cone; that is, the intersecting edge of two coaxial conical surfaces. With this indenter, we are able to produce suitable indentations in soft as well as hard materials, such as sintered carbides, silicon carbide, boron carbide and corundum. Hitherto we only observed in these hard substances an elastic deformation which recovered after removal of the load. The double cone, owing to the long measuring length (Fig. 2), has much advantage for testing of sintered carbides.

P. GRODZINSKI
Diamond Research Dept.
Industrial Distributors (Sales) Ltd.

Fig. 2 — Double-Cone Indentations in Sintered Carbide. 500 ×





Authors . . . IN THIS ISSUE

Junius D. Edwards

Upon graduation from the University of Minnesota, Mr. Edwards spent six years in research at the National Bureau of Standards. At the end of World War I he became associated with Francis C. Frary in the newly-formed research laboratories of Aluminum Company of America. Since becoming assistant director of research in 1921, he has made a career with Alcoa and been interested in many branches of the aluminum industry. The development of aluminum powder pigment and aluminum paint has been a field with which his name has been closely connected and he has authored two editions of the book "Aluminum Paint and Powder". "The Aluminum Industry", written with Frary and Jeffries and published in 1930, covered all phases of the aluminum industry. Finishes for aluminum and particularly anodic coatings constitute another field in which Mr. Edwards has been an active investigator.

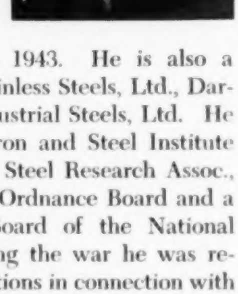
Antonio Scortecci

A long and varied career in metallurgy has preceded his present position as research director of "Finsider" (holding company for Italian Steelworks), Genoa, Italy. One of Italy's foremost metallurgists, Professor Scortecci began his life's work as an assistant at the General Chemistry Institute in Florence in 1919. In 1921 he was appointed chief of the physics and chemistry departments at the technical scientific institute of E. Breda's Works in Milan, progressing to chief of the arms and tools parts division in the Breda Works in Rome in 1929. From 1930 to 1936 he was chief of Ansaldo's steelwork laboratory, becoming a lecturer in metallurgy and metallography in 1936. He has been a lecturer in metallurgy at Genoa University since 1938. In 1937 he became general manager of the ILSSA works, then becoming service chief manager of the ILVA Rolling Mills and Steelworks. He has been research director of "Finsider" since 1948; vice-president of the Italian Metallurgy Association since 1946; and an honorary member of the French Society for Metallurgy since 1950. He was a member of the metallurgical research group at the First World Metallurgical Congress in Detroit in October 1951.

L. G. Beresford

A graduate in metallurgy of the University of Birmingham and Fellow of the Institution of Metallurgists, he has been a lecturer for many years. He was appointed to his present position of editor of *Metal Industry*, the well-known British journal of nonferrous metals, in 1941. He is past-president of the London branch of the Institute of British Foundrymen.

H. H. Burton



Now the director of metallurgy and research at English Steel Corp., Ltd., Sheffield, England, Mr. Burton has been with that corporation since 1929 when he was appointed senior assistant to the chief metallurgist whom he later succeeded. He was appointed a special director in 1938 and a director in 1943. He is also a director of Firth-Vickers Stainless Steels, Ltd., Darlington Forge, Ltd., and Industrial Steels, Ltd. He is a vice-president of the Iron and Steel Institute and of the British Iron and Steel Research Assoc., an associate member of the Ordnance Board and a member of the General Board of the National Physical Laboratory. During the war he was responsible for many investigations in connection with steels for aircraft, gun forgings, and naval, tank and aircraft armor, having been chairman of the Cast Armor Advisory Committee for several years. He

(Continued on p. 144-B)

AUTHORS . . . in this issue

(Continued from p. 144)

has taken an active part in problems arising from the rearmament plan as chairman of the Alloy Steel (Rearmament) Technical Committee and is also a member of the Metals Economy Committee of the Ministry of Supply. In the 1952 New Year's Honours list, Mr. Burton was awarded the C.B.E. and also received the Bessemer Medal of the Iron and Steel Institute for services to the steel industry and metallurgy.

John S. Marsh

In his work for a number of years in the general research department of Bethlehem Steel Co. he has been principally concerned with process metallurgy and steelmaking operations in general. A member of the American Iron and Steel Institute's Openhearth Steelmaking Committee, he has also been active in the Openhearth and the Electric Furnace Committees of the American Institute of Mining and Metallurgical Engineers. Previous to joining Bethlehem, he was a member of *Alloys of Iron Research* editorial staff. He has received the Hunt Medal and the A.I.S.I. Medal for papers on openhearth operation and has authored many works, including "The Alloys of Iron and Silicon", "Principles of Phase Diagrams", and the "Alloys of Iron and Nickel – Vol. I".

Achille G. Lefebvre

After completing studies at the Mining University of Belgium, he started in the industry as blast furnace engineer in Belgium and France, then became technical secretary to the general manager of an important Belgian steel plant. In 1934 he joined Solvay & Co. as principal engineer. Since 1937 he is professor of practical iron metallurgy at the Polytechnic Institute of Mons (Belgium). He has published many studies, especially on desulphurization by soda processes, fuel savings in the steel industry, preparation of the blast furnace-burden, and the improvement of the quality of basic bessemer steels. Professor Lefebvre was a member of the group of steelmaking experts which toured this country in 1951 and attended the First World Metallurgical Congress, under the sponsorship of E.C.A. and the American Society for Metals.

A. G. Michel

After graduating as an engineer from the Polytechnic Institute of Paris, he entered the army and served as an artillery officer during World War I with such distinction that he was awarded the Croix de Guerre. He entered industry in 1919 as chief of operations at the J. Holtzer Steelworks and Forge Plant at Unieux, Loire. He later became chief of research, then assistant technical director, and finally technical director. In 1941 he joined the Committee for Organization of the Steel Industry as director of the department of special steels. When the Union for Special Steels was reconstituted in 1946, he became technical director. Since June 1952 he has been a director of the Research Institute for the Steel Industry.

Tom Bishop

Born in Sheffield, England, in 1919, he obtained the degree of bachelor of metallurgy with honors at the University of Sheffield in 1939. After a short period in the research department of William Jessop & Sons, Ltd., Sheffield, he enlisted in the British Army in September 1939 and served until July 1946. He rose through ranks to captain in the Royal Electrical and Mechanical Engineers, working on radar and tank armor development, serving in Norway, Iceland and Germany. He was a member of CIOS and BIOS teams investigating German metallurgical works. After the war, he joined Industrial Newspapers, Ltd. (London) and is now editor of *Metal Treatment and Drop Forging* and metallurgical editor of *Iron and Coal Trades Review*. He is an associate of the Institution of Metallurgists, and a member of the Iron and Steel Institute, Society of Chemical Industry and Institute of British Foundrymen.

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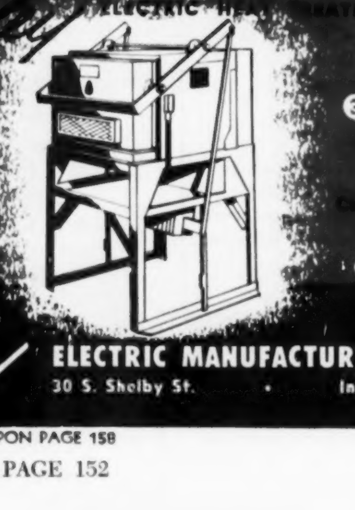

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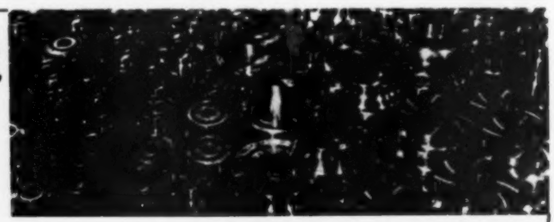

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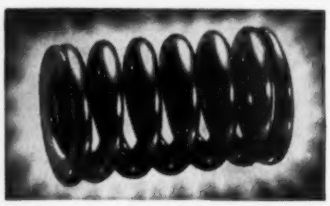

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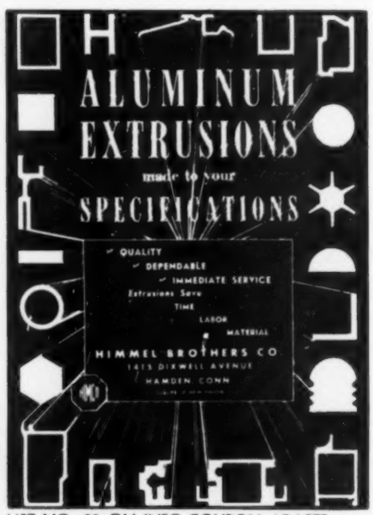

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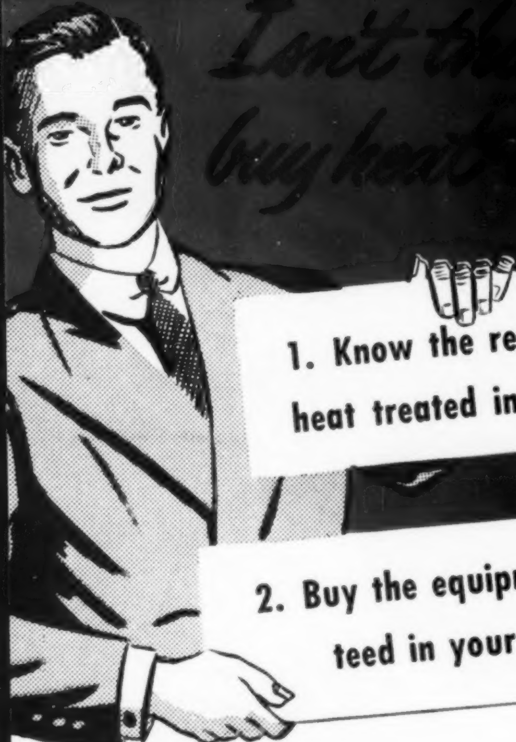

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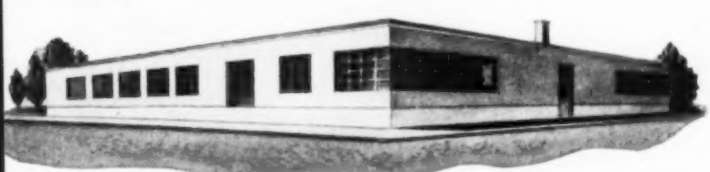

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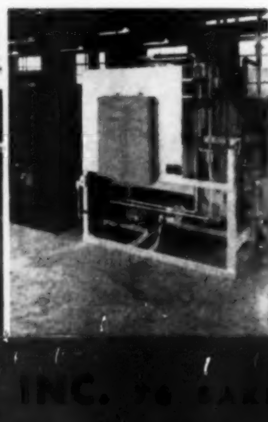

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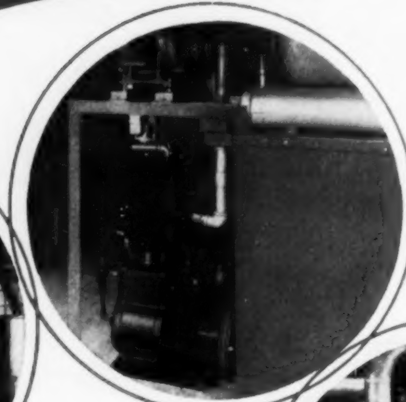
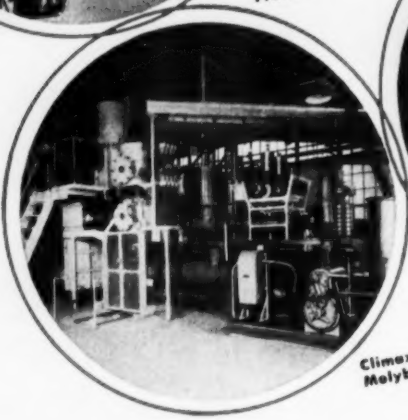
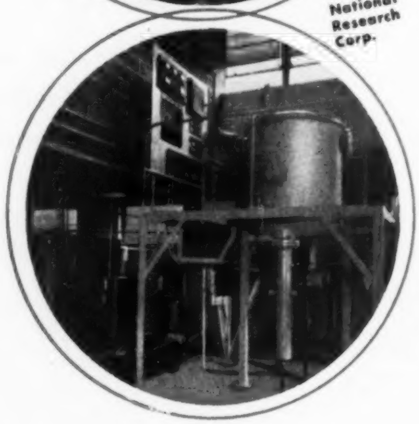
Sylvania Electric Products


Proctor & Schwartz


Climax Molybdenum


Distillation Products Industries


National Research Corp.

- **Sylvania Electric Products is producing super-size TV picture tubes in this giant merry-go-round.**
- **Climax Molybdenum uses this high vacuum furnace for metallurgical research.**
- **Proctor & Schwartz and Dry-Freeze Corporation have developed a process for freeze-drying materials which would otherwise be damaged by high temperatures.**
- **Putting a thin layer of metal on cellophane is the job of this vacuum coating machine made by Distillation Products Industries.**
- **Metals are melted and cast to a new high standard of quality in this National Research Corporation vacuum furnace.**

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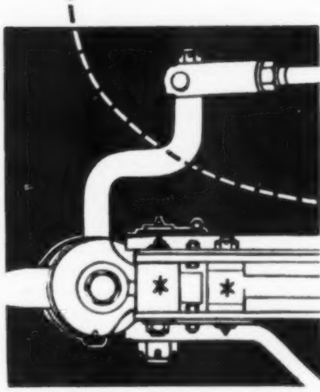
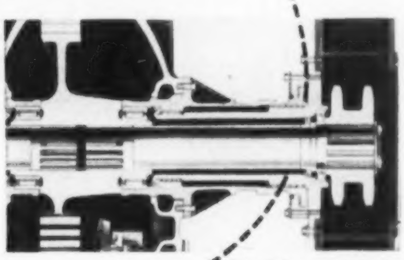


Print showing double reverse bend formed in Adams Grader steering arm made of Republic Alloy Steel.



The drive axle of the Adams Motor Grader shown above is Republic Alloy Steel.

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Personals

After obtaining a Ph.D. degree at Lehigh University, **Eugene G. Zukas** has accepted a position as staff member, Los Alamos Scientific Laboratories, Los Alamos, N. M.

R. D. Barer, who was formerly metallurgical engineer with Consolidated Mining & Smelting Co., Ltd., of Trail, B. C., is now supervisor of the metals-chemistry section of the Pacific Naval Laboratory, British Columbia.

G. Willard Quick, metallurgist in the mechanical metallurgy section, has retired after more than 34 years service at the Bureau of Standards. His work in recent years consisted principally of investigation of the causes of failures in metals. Since 1926 he has been technical secretary, and since 1946 vice-chairman of the Metals Committee, Federal Specifications Board. He has served on several committees of the American Society for Testing Materials, and as secretary in 1926-27 and chairman 1934-35 of the Washington Chapter.

Succeeding Jacob D. Cox, who for a third of a century has directed The Cleveland Twist Drill Co., is **Arthur S. Armstrong**, who has been promoted from executive vice-president to president and general manager. Art Armstrong joined The Cleveland Twist Drill Co. 20 years ago as a special apprentice in the mechanical department and rose in 10 years to a position in the administration.

Joseph V. Emmons, chief metallurgist since 1909 of The Cleveland Twist Drill Co., has been elected to the board of directors of that company. Emmons is a pioneer member of, being the first chairman of the Cleveland Chapter, and national treasurer in 1921-23. He originated the successful molybdenum-tungsten high speed steel trade-named "Mo-Max", for which he received the Howe Medal of the.

Charles T. Evans, Jr., has accepted the position of manager of high temperature metals at Universal-Cyclops Steel Corp., Bridgeville, Pa. He will make his headquarters in the executive offices where he will be closely associated with all phases of activities involving high temperature metals. Mr. Evans was with Elliott Co., Jeannette, Pa., for several years, and was director of development and metallurgy until his recent resignation.

Glen W. Wensch has been promoted to Chief, Materials Branch, of the Savannah River Operations Office at Wilmington, Del. He will administer those research, development, design, fabrication, installation and equipment operation activities concerned with reactor materials and special feed materials, for which the Wilmington Area Office of the Atomic Energy Commission is responsible. He was also recently appointed a member of the AEC Welding Committee. Prior to becoming associated with the Atomic Energy Commission in May 1952, Dr. Wensch was senior research metallurgist at the Fansteel Metallurgical Corporation and had been a staff member of the Los Alamos Scientific Laboratory.

Richard P. Seelig, formerly vice-president of American Electro Metal Corp., Yonkers, N. Y., has recently been named executive vice-president, Chromalloy Corp., New York. He has been active in the field of powder metallurgy and related fields for the past 15 years, and has been associated with the development of a chromizing process used in production of jet engine compressor blades.

Personals

Stanley A. Sczypek recently resigned from the materials section of the engineering services, Sylvania Electric Products Inc., Emporium, Pa., to accept a position as production engineer with the Pittsburgh Ordnance District.

Gerald C. Gardner, upon release from service with the U. S. Air Force, is now chief metallurgist at the tin mill, Jones & Laughlin Steel Corp., Aliquippa, Pa.

H. S. Lewis has been promoted to assistant manager of advertising in the Nickel Sales and Inco Nickel Alloys Dept., International Nickel Co., Inc., New York City. He has been editor of *Nickel Topics* since 1932, and was for several years secretary of the New York Chapter.

A. M. Cox, president of Pittsburgh Commercial Heat Treating Co., Pittsburgh, was elected president of the Metal Treating Institute at its annual meeting. He is also president of J. P. Devine Mfg. Co. and Pittsburgh Wire Form and Mfg. Co.

Paul R. Rauch has been appointed assistant chief inspector for the Youngstown District of The Youngstown (Ohio) Sheet and Tube Co. He has been with the company since 1939 and until his recent promotion was general foreman of Campbell Works inspection.

J. H. Bradley has been appointed vice-president in charge of the Chicago office by Holcroft and Co., designers and manufacturers of heat treat furnaces.

J. K. Munhall, owner and operator of the J. K. Munhall Co., manufacturers representative in Buffalo for the Detroit Electric Furnace Div., Kuhlman Electric Co., announces that his company has merged with Eastern Foundry Supplies, Inc., Newark, N. J. Mr. Munhall has moved his offices to the Newark address.

J. J. McGrann, sales engineer in the Los Angeles office of The Timken Roller Bearing Co., has been transferred to the Houston office of the company.

James S. Kirkpatrick, director of research and development for Brooks & Perkins, Inc., Detroit, has been elected president of The Magnesium Association. Under his administration, the association will hold an International Magnesium Exposition next spring in Washington, D. C.

Harold C. Olson has been named works metallurgist for the Los Angeles plant of the Lindberg Steel Treating Co. He was formerly works metallurgist at the Melrose Park, Ill., works of International Harvester Co.

Victor H. Moore, formerly employed by Claud S. Gordon Co., is now employed by Service Associated, Inc., Chicago, as a member of their pyrometer service engineering staff. Mr. Moore is a registered professional engineer and a veteran of over 34 years in the field of industrial furnace and control systems engineering.

Ernest H. Wyche has recently joined Kenneth Tator Associates, Coraopolis, Pa. He was formerly with the materials engineering division of Colgate-Palmolive-Peet Co., Lukens Steel Co., and U. S. Steel Co. A graduate in chemistry from the University of North Carolina, he is the author of numerous technical publications and holds several patents, particularly in the field of manufacture and use of corrosion prevention methods.

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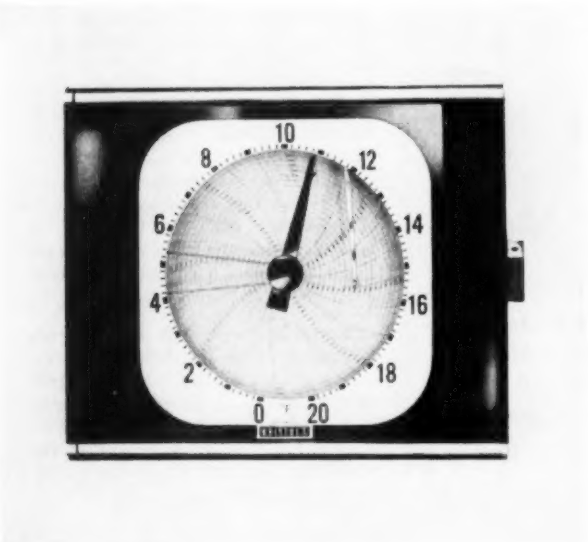

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Personals

Richard J. Haffeman has recently been transferred from the materials engineering department of the Deere & Co., Moline, Ill., to the John Deere Ottumwa Works, Ottumwa, Iowa, as assistant plant metallurgist.

Delbert Dallefeld resigned from Caterpillar Tractor Co., Peoria, Ill., and has accepted a position as design engineer at McDonnell Aircraft Corp., St. Louis.

John L. Young, vice-president in charge of engineering for U. S. Steel Co., was elected president of the Association of Iron and Steel Engineers for 1953. **John H. Vohr**, general superintendent, Gary Steel Works, U. S. Steel Co., was elected second vice-president.

C. A. Christian has resigned as teacher of metallurgy and heat treating with West Allis School of Vocational and Adult Education to accept a position as metallurgist with Nash-Kelvinator Corp., Aircraft Engine Div., Kenosha, Wis.

Robert T. C. Rasmussen resigned from the U. S. Bureau of Mines after 12 years as a metallurgist, to accept a position with Quebec Metallurgical Industries, Ltd., Canada.

John C. Barrett is acting chief, physical metallurgy branch, U. S. Bureau of Mines, College Park, Md. The activities of this branch are concerned with research in the physical metallurgy of titanium and its alloys.

George O. Shutzbaugh has joined the research and development staff of Alloy Engineering & Casting Co., Champaign, Ill., as an associate director of Armed Services Research and Development Projects. Mr. Shutzbaugh was formerly assistant chief of the Ferrous and Nonferrous Metal Section, Directorate of Industrial Resources, Headquarters, U. S. Air Force. Previous to recall to active duty in the Air Force, he was plant manager of the South Illinois Foundry Co., Carmi, Ill.

Frank B. Bayless, for 33 years a member of the Pittsburgh Chapter, has retired after 35 years as chief metallurgist and assistant to works manager, Imperial Works, Oil Well Supply Division, U. S. Steel Co., Oil City, Pa. He will engage in metallurgical consultation work.

A. J. "Gus" Mueller has established The A. J. Mueller Co., technical sales engineers, in Atlanta, Ga. The company will serve the Southeast, representing several leading manufacturers of metalworking equipment and supplies as well as offering technical assistance. Mr. Mueller was formerly research metallurgist and field engineer for the Tocco Div., Ohio Crankshaft Co.

George W. Stamm has been appointed to a newly created position of assistant to the vice-president in charge of sales at Crucible Steel Company of America, Pittsburgh. **Robert C. Kuhn** succeeds Mr. Stamm as manager of the Cleveland sales branch.

Herbert D. Cronin, formerly with Harrington & Richardson Arms Co., is now assistant chief metallurgist at Morse Chain Co., Ithaca, N. Y.

R. C. Lindsay, after receiving a master's degree from the University of Pennsylvania, has accepted a position in the engineering administration section of RCA Victor Div., Camden, N. J. Prior to attending graduate school, he was employed as a sales and metallurgical engineer by Utica Drop Forge & Tool Corp. and General Electric.

Postwar Trends in German Welding Technology

(Continued from p. 134)

fairly be said that Germany was a leader in this field. At that time these naval projects were governed by the Versailles Peace Treaty, which set up rather drastic limitations on the gross weight of warships. Ships' hulls were welded and much weight was saved, thus permitting the installation of heavier armament. The experience so gathered was rapidly put into use by other branches of manufacturing.

Since 1936 the German engineer has been continually plagued with a shortage of material, due to the limited capacity of our steel plants. It was necessary to conserve material in order to attain the highest possible production with his quota. Welded construction was again the solution.

Then the time came to conserve alloys which could not be obtained in our own country. The blockade sharpened this situation. In this emergency the solution was found through the development of clad materials, whose commercial production rests essentially on information which welding technology has produced. In addition, the use of clad materials demanded the extensive application of welding.

Postwar shortages in all fields led to the repair of parts damaged through fracture, wear, or war's devastation by extensive use of available welding methods. Truly, welding has been indispensable to such recovery as we have been able to achieve. This reconstruction began in 1948. An acute shortage of material still exists, so that further savings by restoration of destroyed bridges, roads, buildings, and machine tools had to be undertaken.

In many instances, welding alone was incapable; new designs were necessary. Monocoque construction, well known to aircraft builders, was carried into the above-mentioned fields.

While the German constructor therefore looks upon the welding engineer as an ever-present help in time of trouble, it would not be proper to make sweeping claims. Unfortunately, accurate statistics have not been gathered, and consequently figures cannot be cited to indicate its relative importance. Conservative estimates indicate that there are nearly 450 German firms engaged in the manufacture of welding gases, electrodes, and equipment, whose payrolls gross about 400,000,000 German marks ($96,000,000).

Value of new welding equipment sold in 1949 totaled about 41,500,000

(Continued on p. 170)

Whose cheese is being divided?

TWO cats could not agree on fair division of a tasty cheese. "Let's go to the monkey," said one, "He is all-wise and can divide our cheese fairly." So to the monkey they went.

The monkey immediately broke the cheese evenly and judicially put the two pieces on the pans of his balance. But one was slightly heavier. He shrewdly nibbled that piece a bit and put it back on the scales. Now it was the lighter piece. So he bit off some of the other piece only to find it the lighter. Thus while the two hungry cats watched, the monkey kept taking bites of the cheese, first one piece, then the other, until finally the cheese had almost disappeared.

"What's left is too small to divide," sagely pronounced the monkey, as he popped the remaining fragments into his mouth.

Observers of the American scene see a direct parallel between the record of federal taxation and this ancient parable of the trusting cats, the greedy monkey and the cheese. Business and the individual citizen have been content to trust government to rule on the disposition of their earnings. And Uncle Sam keeps taking bite after bite out of the shares of both individual citizen and business.

Already government bites are so large as to severely penalize citizens and business alike. If allowed to continue, it will seriously impede further industrial progress and growth, stifle initiative and threaten the strength of our free enterprise system. Beware the day—goal of the socialists among us—when the monkey says, "What's left is too small to divide."

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Postwar Trends in German Welding Technology

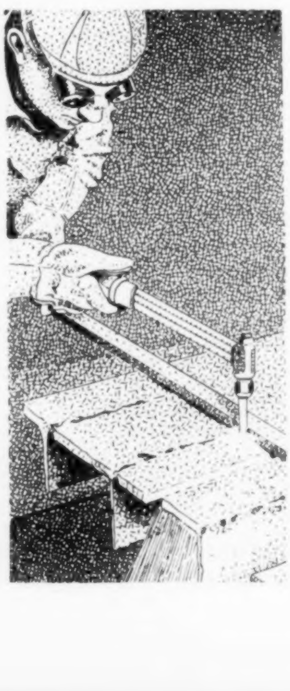
(Continued from p. 168)

marks ($10,000,000), of which about 35% was for autogenous welding and 65% was for electric welding. In 1951 about 57,500 short tons of weld rods and electrodes were made (about three quarters of which went into unalloyed coated electrodes). This amounts to about 0.36% of the German steel production – a relatively high proportion, being one and a half times as much as in the United States.

SUMMARY

The above account of welding processes in Germany will give the contemplative reader a little insight into the European economic situation since the war. Many differences exist between German and American practice (the latter as viewed during the study tour prior to the ⊕'s First World Metallurgical Congress). Wide-scale destruction of bridges, roads, plant, machinery, and transportation equipment all but paralyzed German life immediately after the war. Welding techniques have enabled us to salvage a surprisingly large amount of this wreckage; in conjunction with weight-saving design, we are now able to stretch our limited amount of metals over a gratifying range of new construction.

Another interesting point of difference with America is that the national welding association is responsible for organizing the education of the operators and supervisors. ⊕

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Metal Resources of the Free World

(Continued from p. 73)

by the current annual rate of consumption, would often give an alarmingly short life if interpreted as the period in which an acute shortage of metal would have developed. The "known" reserves may not be determined more than 4 or 5 years ahead of mining, so that there is a continual process of reassessment.

The whole question of mineral reserves is complicated by the fact that ores are not mined until it is judged that it will be profitable to do so. Consequently in times of high real prices for metals, relatively poor ores repay working and are realizable reserves, but at a lower price level for the metal, they are not to be reckoned as commercially available. In the same way advances in the technology of concentration and extraction can make a previously worthless deposit viable.

Space does not permit adequate treatment of the subject of reserves and their relation to the anticipated demands over the next 25 years, but brief reference may be made to the highlights of the survey in the Paley Commission's reports. Among the five major basic metals (iron, copper, zinc, lead and aluminum) and eight metals of importance in steelmaking (manganese, chromium, nickel, molybdenum, cobalt, tungsten, vanadium and columbium), those in which estimated reserves – measured, indicated and inferred – would provide less than 50 years' supply at 1950 rates of world consumption are zinc, lead, tungsten and columbium. These are the four metals which most urgently demand attention by the search for new mineral sources, conservation of supplies, greater efficiency in use and recovery of scrap, and by substitution. It should be emphasized that in mentioning only these four metals, attention is being concentrated on those in which there is thought to be little prospect of early alleviation of current shortages. This does not minimize the importance of the efforts now being made to achieve economies in the use of nickel, molybdenum and cobalt in alloy steels made necessary by short-term deficiencies in supply.

SUBSTITUTION

Although much must remain obscure and a high degree of precision cannot be claimed, it is possible to discern the main features of the pattern in the future utilization of metals. Nothing is going to displace steel

(Continued on p. 174)

Metal Resources of the Free World

(Continued from p. 172)

from its majestic position. To meet the increasing demands, obvious developments are the opening of high-grade deposits of iron ore in new localities and technical advances in the treatment of lower grade ores. In the nonferrous metals, aluminum will provide a rapidly increasing proportion of the total consumption. By taking over many of the present applications of the older metals – copper, zinc, lead and tin for which they are not essential – it will enable the heavier metals to be used where their individual characteristics are indispensable. The rate at which increasing supplies of aluminum will become available will depend almost entirely on electric power, since the mineral reserves, primarily as bauxite but, in the second line, as clays, are far in excess of any imaginable requirement. Magnesium could make an important contribution, also limited only by the availability and cost of electric power. Titanium must also be given a place if only from its importance among the minerals of the earth's crust. Its relative significance will be decided by the degree of success attained in the present search for cheaper methods of production.

POSITION OF THE U. S.

In discussing the resources and requirements of the free nations, this review has sought to treat all those nations as a single entity. It would be unrealistic, however, not to refer to some of the considerations which must cause metal users outside the United States to view the statistics and estimates in a different light from that in which American members of the comity see them. Prominent among these considerations is the fact that while the Americans have always been dependent on other continents for the bulk of their manganese, chromium and tungsten, it is only within the last ten years or so that the United States has become a net importer of iron ore, copper, zinc and lead. This is, of course, only another manifestation of the very high rates of manufacture in the United States relative to the rest of the world.

With their country's enormous appetite for the necessities of industrial life, Americans may recall the words of Gulliver describing the emotions of the Lilliputians among whom he found himself: "They supplied me as far as they could, showing a thousand

(Continued on p. 176)

Metal Resources of the Free World

(Continued from p. 174)

marks of wonder and astonishment at my bulk and appetite. They apprehended that my diet would be very expensive and might cause a famine." But the rest of the free world would find reassurance, if it were needed, in a declaration and an act by the United States.

The declaration is the third "fundamental concept" given this year as a conviction held by the members of The President's Materials Policy Commission. "We believe that the destinies of the United States and the rest of the free non-Communist world are inextricably bound together. If the United States is to increase its imports of materials it must return in other forms strength for strength to match what it receives. It is this Commission's belief that if we fail to work for a rise in the standard of living of the rest of the free world, we thereby hamper and impede the further rise of our own, and equally lessen the chances of democracy to prosper and peace to reign the world over."

The act was the setting up of the International Materials Conference in 1951 with the object of insuring the equitable distribution of the raw material resources of the world. Its schemes of allocation have been an undoubted success in a situation with obvious potentialities for chaos and hardship. No less hopeful is the establishment by the Conference of technical committees advising on the problems of conservation, substitution and reclamation among the most strategically critical metals.

Metallurgy in Italy

(Continued from p. 93)

tests, and they pass through a 12-month course. Their first task is to get a more advanced knowledge of physics of metals and metallurgy. Their theoretical and practical knowledge is then coordinated by a series of visits to plants where they concentrate on the several stages of manufacturing, such as coke plant, blast furnaces, rolling mills, and so on. Up to date, more than 4000 men have been examined, from which 800 have been admitted, and 250 have completed their training, and are employed throughout the industry.

B. Setting up and prosecuting research on manufacturing operations. Proposed subjects are first examined by committees composed of techni-

(Continued on p. 178)

Photo shows installation of AJAXOMATIC Combined Holding Furnace and Automatic Pouring Unit in connection with die casting machine. In circle at right is shown a closer view of the spout from which uniform shots of molten aluminum alloy are ejected at exact time intervals.

NOW completely automatic die casting of aluminum alloys is possible in smaller quantities than formerly, and at reduced cost. This fact should be of special interest to the manufacturer who has die casting machines in operation and is doing hand ladling. The unit is entirely sealed, the operator feels no heat, accident hazard is eliminated.

This small, compact AJAXOMATIC* unit will increase production of die castings by as much as 25%, because it delivers regular, uniform quantities of metal into the die casting machine with no delay, immediately after dies are closed. The spout itself is heated and the temperature of each metal shot remains constant.

*Patents Pending

For further information send for descriptive folder A-5

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AJAX ELECTRIC CO., INC., The Ajax Hultgren Electric Salt Bath Furnace
AJAX ELECTRIC FURNACE CORP., Ajax Wyatt Induction Furnaces for Melting

Metallurgy in Italy

(Continued from p. 176)

cians of the whole Finsider staff, and are thereafter developed by smaller working committees composed of plant engineers and the institute's researchers. Experiments are carried out in the laboratories and factories of the "Finsider" combine. There are now 13 working committees investigating about 120 subjects.

C. Widening the professional horizon of technicians and engineers within the combine, by regularly supplying them with bibliographical cards and translations of the foreign papers that pertain to those matters with which each of these people is professionally concerned.

Research is by no means confined to this one activity. All major metallurgical firms have re-established and developed their laboratories. Links between investigators and practical men within the whole industry are closer and closer.

For example, the Istituto Sperimentale dei Metalli Leggeri, founded in 1937 by the Società Montecatini and Società Alluminio Veneto, aims to expand the use of aluminum and its alloys by widening the scientific and technical knowledge on the properties of these materials and spreading such information among producers and consumers.

This institute possesses complete semi-industrial installations for the experimental production of machine parts and appliances of light alloys, as well as research laboratories which have installed modern equipment. An excellent library service is also a part of the institute's program, the journal *Alluminio* being issued regularly.

The Metal Industry in Japan

(Continued from p. 114)

Processing Techniques – Prices of ingot metals in Japan are generally higher than the international level. In consequence, it is of vital importance, if nonferrous metal products are to be exported, to cut down the cost of their production through modernized processing. Many advanced techniques are to be introduced from abroad for this purpose.

The continuous casting of wire bar or slab is one such technique. It was introduced during the war for processing of some light alloys, and has recently been widely applied to copper wire bar and cakes. Further, our metallurgists plan on connecting continuous rolling mills directly to the continuous casting unit for manufac-

turing aluminum, lead, copper strip, bars and rod.

Bright annealing has been widely adopted. Great improvements in quality have been made in special phosphor bronzes.

It has been necessary for Japan to use various metals with great frugality. Proper substitutes have been intensively studied since the war; great progress has been made. For example, nickel has been the most scarce metal in Japan for some time, and other metals and alloys have superseded it in vacuum tubes and other communications equipment.

Great contributions have been made in the use, by substitution, of aluminum-clad iron, oxygen-free copper and beryllium copper. A special phosphor bronze has been substituted for nickel silver.

The die-casting method is scarcely used in Japan; there is little demand for such products.

CONCLUSION

The loss of its overseas markets, in addition to the destruction and superannuation of plants and equipment caused by the war, has made the rapid recovery of this country's metal production exceedingly difficult. As Japan's early industry was long isolated from the rest of the world, many sharp anomalies can be witnessed in our technical progress, which in turn result in a general lowering of the average technical standard. Thus, it is most important for us to promote the active introduction of the best techniques of the rest of the world.

Many difficulties must be surmounted. It is first of all necessary for Japan's industry to accumulate the necessary capital in spite of intensified competition on the international market. Next, due to restrictions from the national circumstances under which Japan is placed, the most advanced techniques cannot always be applied to our industry in their original form. We must foster and improve those original operations which match the actual conditions of this country. This in itself will raise the technical standard of this country and facilitate the proper introduction of ideas and processes from abroad.

In the seven years since the war, the recovery of Japan's metal industry is fairly well under way. The production standard having reached its prewar level, there remains much to be done toward strengthening its economic and technical basis. Only a small part has been accomplished of that which has been planned as necessary. The success or failure of such a plan depends entirely on the future effort of our people.

The Blast Furnace Industry in the U. S.*

THIS IS A COMPREHENSIVE paper inasmuch as it gives a complete summary of American trends in the design, construction and operation of blast furnaces.

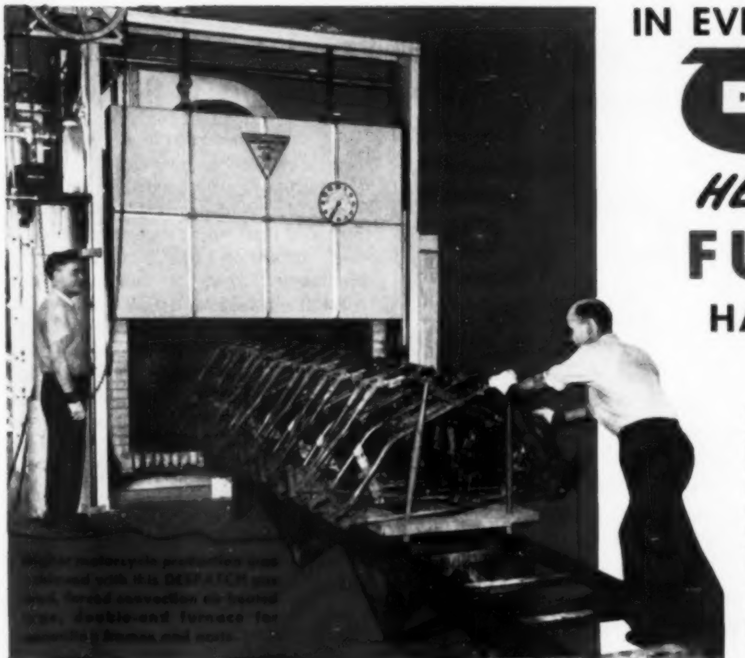
The production and capacity rating of blast furnaces is calculated on the ability of the furnace to burn coke under normal blast pressure and blast temperature. The basis of this rating is the area of an annulus six feet in front of the tuyeres and the assumption that 5400 lb. of carbon will be burned per 24-hr. day per sq.ft. of area in this annulus. For example, a furnace with a 20-ft. hearth has an annulus area of 210 sq.ft. and should burn 1,460,000 lb. of coke per day; a 25-ft. hearth furnace should account for 2,050,000 lb. per day. An approximate formula: Rating (100%) = 6300 × 18.5 (d-6-1.5) lb. of coke per day, where d is the hearth diameter. This shows that a 15-ft. hearth furnace will consume 1 million lb. of coke per day, a 25-ft. hearth furnace 2 million lb. per day and a 30-ft. hearth furnace 2 million lb. per day. Assuming a nominal coke consumption of 1 ton of coke per ton of iron, the formula yields a logical basis for estimating the pig iron production of various size blast furnaces.

The author next provides very complete operating data in seven tables which give a comparison between 107 American furnaces for 1950, 11 furnaces in Great Britain, 3 in Holland, 3 in South Africa, 2 in India and 1 in Brazil. The tables have 12 columns which give hearth diameter, coke potential per day, pig iron output, coke per ton of iron, actual coke burned per day, per cent of capacity output, slag weight per ton of iron, dust weight per ton of iron, sinter per ton of iron, blast temperature, per cent Si in iron and total production on current lining. This is a very useful condensation of most of the important operating factors in blast furnaces.

Temperatures of the hot blast average 1025° F. for all American furnaces. At 95 northern furnaces using fine Superior ore, the average temperature is 975° F., and the author states that the postulate "you can't carry a high blast temperature with lake ore" is not entirely logical. Eight northern furnaces operating on high-grade lump hematite ores used an average

(Continued on p. 182)

*Digest of "Some Aspects of the Blast Furnace Situation in the United States", by Owen R. Rice, *Journal* of the Iron and Steel Institute, Vol. XX, February 1952, p. 89-108.



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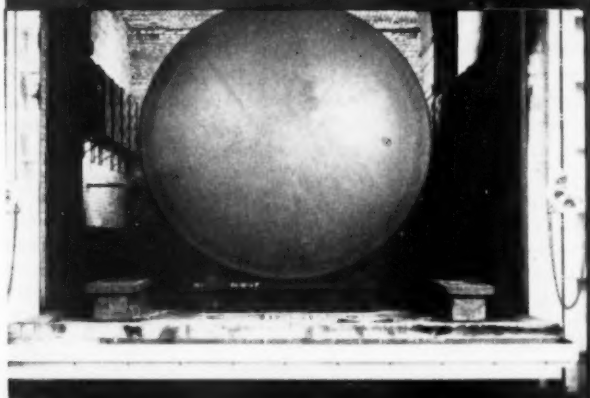

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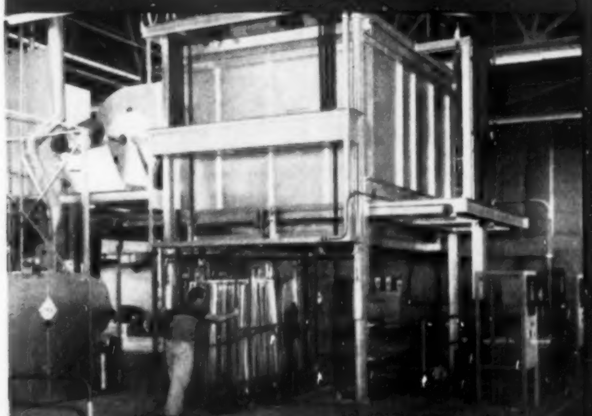
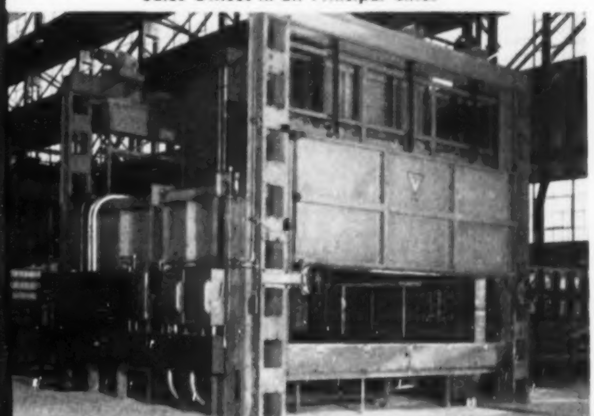


Rigid uniformity and rapid quench are being achieved in this aircraft plant with this DESPATCH bottom entry quick-quench furnace for aluminum heat treating.



This DESPATCH carloaded, double-end furnace is used for heat treating vehicle frames. Just now it is playing a doubly significant role in Defense Production.

PIONEERS IN ENGINEERING HEAT APPLICATIONS FOR INDUSTRY

The Blast Furnace Industry in the U. S.

(Continued from p. 180)

blast temperature of 1390° F. with lower coke consumption. The southern furnaces using hematites containing 35% iron employ an average blast temperature of 1135° F. in 1950. The abstracter knows of four southern blast furnaces now (1952) using blast temperatures of 1500° F. with greatly decreased coke consumption and low loss of flue dust (under 50 lb. per ton).

The critical American iron ore situation is also reviewed and quite optimistic conclusions are reached. Estimates of available lake ores are given as 1200 million tons (direct shipping ores) of which 50% may be recovered in open pits and 50% by underground mining. Based on D. B. Gillies, whom the author quotes, the available direct shipping ores not needing beneficiation are assumed to be double the amount declared for tax purposes. This approximates 2500 million tons, sufficient for nearly 25 years at current consumption.

The author further estimates that there are sufficient magnetic taconites in the Lake Superior region to yield 2000 million tons of 63% Fe concentrates by commercially feasible methods. This is equivalent to 2500 million tons of 50% Fe direct shipping ores and would extend the life of the lake-region reserves for another 25 years. This seems to be a conservative speculation in regard to the taconite reserves, since only 6 billion tons of taconite would be consumed and it is well known that over 72 billion tons of taconite (mostly hematitic) remain.

Further iron ore data indicate that 25% of the lake ores now originate from costly underground operations and that 25% of the ore mined is now subject to beneficiation – mostly log washing and jigging – with some heavy media plants. Moreover, the consumption of sinter in 1950 amounted to 21 million tons of which about 6 million tons is recycled flue dust. Imports of foreign ores in 1950 were 9 million tons, and the author states that possibly 30 million tons of high-grade foreign ores from Labrador and Venezuela should be available within the next few years. He concludes: "The iron ore supply situation in the United States calls for energy and enterprise, but it is neither grim nor hopeless."

In the section on coal and coke, estimates of available supply are very difficult to reach. Using a figure of 1,213,000 million tons of total coal reserves in the United States and as-

(Continued on p. 184)

The Blast Furnace Industry in the U. S.

(Continued from p. 182)

suming that only 1% of this is low-volatile coking coal, 50% of which can be mined, there remains only 6000 million tons of recoverable low-volatile coking coal. At present about 80 million tons of this is consumed annually, 20 million in coke ovens and 60 million for semismokeless domestic fuel. It is estimated that this reserve will provide a source of metallurgical coke for 60 to 120 years. The benefits of coal washing (prior to coking) on blast furnace operations are discussed and the importance of this is shown by the increase in washed coking coal from 30% of the total in 1944 to over 60% in 1950.

In the section on refractories it is estimated that the average lining of fireclay brick will permit the production of 1,750,000 tons of pig iron before relining. This is based on the survey of the 107 American furnaces. Using an average daily output of 950 tons per furnace, the expected average life of such brick lining is 1830 days or about five years. This increased life is attributed to improvements in refractory brick manufacturing such as power press forming, de-airing to decrease the porosity, and especially to hard burning in a reducing atmosphere which converts the iron compounds in the clay mixture to ferrous silicate.

On the subject of carbon refractories, so successfully used in British furnaces, the author states that early American objections to carbon have gradually been overcome by a better understanding of proper installation methods. So far 86 carbon hearths have been used in American blast furnaces and "the great majority of carbon users . . . were satisfied with the material. Serious consideration is even being given to all carbon linings, as advocated by Elliott, and it is interesting to speculate that if a carbon-lined bosh and lower inwall would promote smoother stock descent and thus increase of blast temperature at northern United States furnaces from the present average of 975 to 1175° F., the resulting coke economy might be $200,000 per furnace per year."

Experience on the six furnaces using high-top pressures has shown that operational troubles and delays have been largely overcome. It has been demonstrated that greater production (5%) and lower coke consumption result from this practice. Dust loss is greatly reduced and a smoother working furnace is also an advantage. The

(Continued on p. 186)

The Blast Furnace Industry in the U. S.

(*Continued from p. 184*)

present thinking on this feature is that more furnaces will be adapted to moderate top pressures (3 to 4 psi.) which will enable operation at either normal or higher pressures.

Application of oxygen-enriched air to the furnace has not progressed very far in the United States. One thorough test with only 3 to 4% oxygen addition showed good results when using a hot blast at 925° F. It was calculated that this oxygen enrichment would be equivalent to a rise of 200 to 300° F. in blast temperature. Since the present cost of oxygen is greater than the cost of increasing the blast temperature to this degree, more extended study of oxygen enrichment will depend upon the economics in any situation.

Interesting cost figures for 1950 are given at the end of the paper. The total cost of raw material assembly is $27.50 per ton of iron; this is obviously based on market prices for raw materials and not on actual costs of an integrated operation. The overhead or cost above averages $4.70 from which an average gas credit of $2.08 is deducted; the net cost above becomes $2.62 per ton. The general expense item of $3.45 in the total overhead cost is divided as follows:

Supervision		$0.66
Steam and Blowing		1.21
Relining Fund		0.33
Handling Materials		0.82
Electric Power		0.07
Casting and Ladles		0.36
Total General Expense		**3.45**
Labor	1.00	
Repair Materials	0.25	
Total Cost Above		**$4.70**

E. C. WRIGHT

Cold-Flow Pressing of Steel*

THIS IS THE FIRST of two articles by a co-inventor of the cold extrusion process in its industrially applicable form. It begins with an outline of the principles of plastic flow followed by a brief description of cold-flow pressing of solid and hollow bodies. The technological mechanics of the process and the selection of metals for pressings are then considered in some detail. Finally, means for minimizing friction between work and tools are discussed.

Knowledge of the plastic stress-

*Digest of "The Development and New Applications of Cold-Flow Pressing of Steel", by K. Sieber, "DRAHT", July 1952, p. 26-30.

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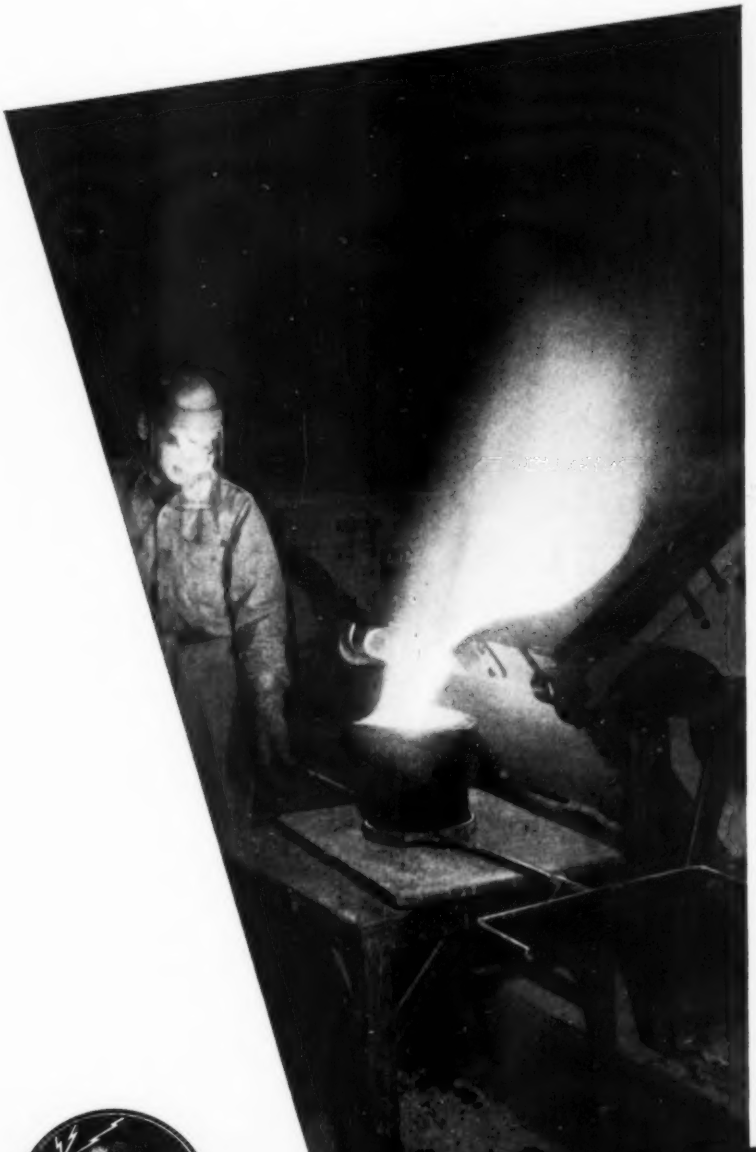

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$60,000 a year pays for the furnaces in short order—and the chromium saved is enough for an extra 70,000 pounds of 18 and 8 stainless steel a month.

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Cold-Flow Pressing of Steel

(Continued from p. 186)

strain characteristics of different metals over a wide range of deformations is essential for calculating the forces required in forming. The construction of true stress – logarithmic strain diagrams is thus described. Since the pressed metal is initially soft but work hardens during extrusion, approximate formulas are given for both true and "mean" resistances to deformation. For determining the actual pressure requirements, a number of semi-empirical expressions are given which are based on the stress-strain formulas referred to above.

Inasmuch as the flow-pressing process subjects the material to compression only, the magnitude of deformation in a single working stroke is limited solely by tool strength and capacity of equipment, but not by the tensile rupture strength of the pressed metal. Accordingly, up to 95% reduction of cross section can be made without difficulty on soft metals such as lead, tin, or aluminum. The author points out the fundamental difference between the conditions of flow in tube or wire drawing on one hand, and cold extrusion on the other. While in the first kind the optimum drawing angle lies between 8 and 20°, in the second this optimum is near 63°. This figure is completely independent of the magnitude of deformation and the coefficient of friction, and it determines the condition at which the total redundant work associated with internal uneven flow and with tool-to-work friction is at a minimum.

Any metal of reasonable ductility can be successfully flow-pressed, but the most important application of the process, both technically and economically, is with steel. For highest deformability at relatively low pressures, low-carbon (0.05 to 0.13% C) openhearth rimming or aluminum-killed steel is recommended. Basic Bessemer may be used where tendency for aging embrittlement and low notched-bar tenacity are not objectionable. For higher strength and suitability for heat treatment, carbon steels with up to 0.45% C or low-alloy nickel or chromium steels are appropriate. Dowel pins were made successfully by this method from 1.1% C steel. Normalized structures are particularly recommended for blanks but subcritically annealed steel is equally suitable if the grain is uniform and fine.

When the pressures are extreme, e.g. in forming cup-shaped bodies from solid pieces of wire, it is advantageous to heat the low-carbon steels

(Continued on p. 190)

Cold-Flow Pressing of Steel

(Continued from p. 188)

beyond Ac_3, water quench, and hold at 1180 to 1240° F. For deformations below 35%, bright drawn stock may be used without a softening treatment. Nonmetallic inclusions, welds and laminations have a disturbing influence and use of steels containing these should be avoided.

Suitable surface pretreatment of the blank to reduce friction is indispensable in this process. For this purpose, phosphate coating (Bonderizing) has proved most successful. The firmly adherent, nonmetallic surface layer produced on the metal by the action of phosphoric acid not only prevents direct metallic contact between material and tool, but is also an excellent lubricant carrier. Soap-water solutions are suitable lubricants for phosphate-coated materials. Especially recommended are very fatty lyes from curd soap slices and prolonged soaking of the phosphatized blanks in warm soap-water solution, since the adsorption of the fatty acids is a time-dependent process. Mineral oil is not adsorbed by the phosphate coating and is therefore not suitable as a lubricant.

N. H. POLAKOWSKI

Formation of Solid Solutions Among Metallic Compounds*

THE VARIOUS chemical interactions among the metals can lead to the formation of *(a)* solid solutions; *(b)* chemical (metallic) compounds with a constant composition, known as daltonide compounds; and *(c)* chemical (metallic) compounds with variable composition, known as bertholide compounds. Metallic compounds can form during the decomposition of a solid solution, and N. S. Kurnakov in 1914 discovered the formation of AuCu and $AuCu_3$ in the Cu-Au system, which exhibits complete solid solubility at higher temperatures. Compounds also form during the crystallization of metallic systems that exhibit limited solid solubility. In such, the daltonide compounds are represented by singular points in composition-property diagrams, while bertholide compounds are represented by sloping lines.

The question of the formation of solid solutions among different metallic compounds is comparable in im-

(Continued on p. 192)

*Digest of "Solid Solutions of Metallic Compounds", by I. I. Kornilov, *Doklady Akademii Nauk SSSR*, Vol. 81, 1951, p. 597-600.

Solid Solutions Among Metallic Compounds

(Continued from p. 190)

portance to the similar phenomenon in pure metals. Several general principles exist that permit one to determine and predict the possibility of the formation of solid solutions among metallic compounds. Thus, continuous solid solutions can form:

1. Among compounds with ordered structures formed by transformations of continuous solid solutions of metals.
2. Among daltonide compounds that form during the crystallization of a mixture of metals.
3. Among bertholide compounds, including interstitial phases.
4. Among compounds of the daltonide and bertholide types.

Necessary conditions for the formation of such continuous solid solutions are that: *(a)* Crystal lattices of the compounds be of the same type; *(b)* chemical binding of the compounds be similar; *(c)* components of the compounds be atomically compatible; and *(d)* the same element (aluminum, for example) be present in each of the compounds and be capable of forming with other analogous elements (iron, nickel, for example) compounds (such as FeAl, NiAl) with an isomorphous structure and the same stoichiometric composition.

As examples of solid solutions formed under the first condition are the systems $AuCu_3$-$PtCu_3$, $AuCu_3$-$PdCu_3$, or Ni_3Fe-Ni_3Mn. These might be called molecular solid solutions of metallic compounds. Solid solutions are to be expected also when the ordered structure is tetragonal; for example, in the systems AuCu-PtCu or FePt-FePd. Also, it must be assumed that continuous solid solutions form among the various sigma phases.

NiAl, CoAl, FeAl, and MnAl are examples of second condition, and the presence of continuous solid solutions among at least the first three has been found experimentally. Ni_3Nb, Ni_3Ta, and Ni_3Ti may be a similar series, as may $MgCu_2$, $MgNi_2$; Mg_3Bi_2, Mg_3Sb_2; NiAs, CoAs, FeAs; and NiAs, NiSb.

Examples of the third are the electron compounds, β, γ, and ε, and such interstitial compounds as TiC-ZrC, NbC-TaC, Mo_2C-W_2C, Fe_3C-Mn_3C and others.

N. V. Ageev and E. S. Makarov are said to be the first to have produced compounds belonging to the fourth type by showing that the daltonide phase NiSb and the bertholide ε-phase in the FeSb system form a continuous series of solid solutions.

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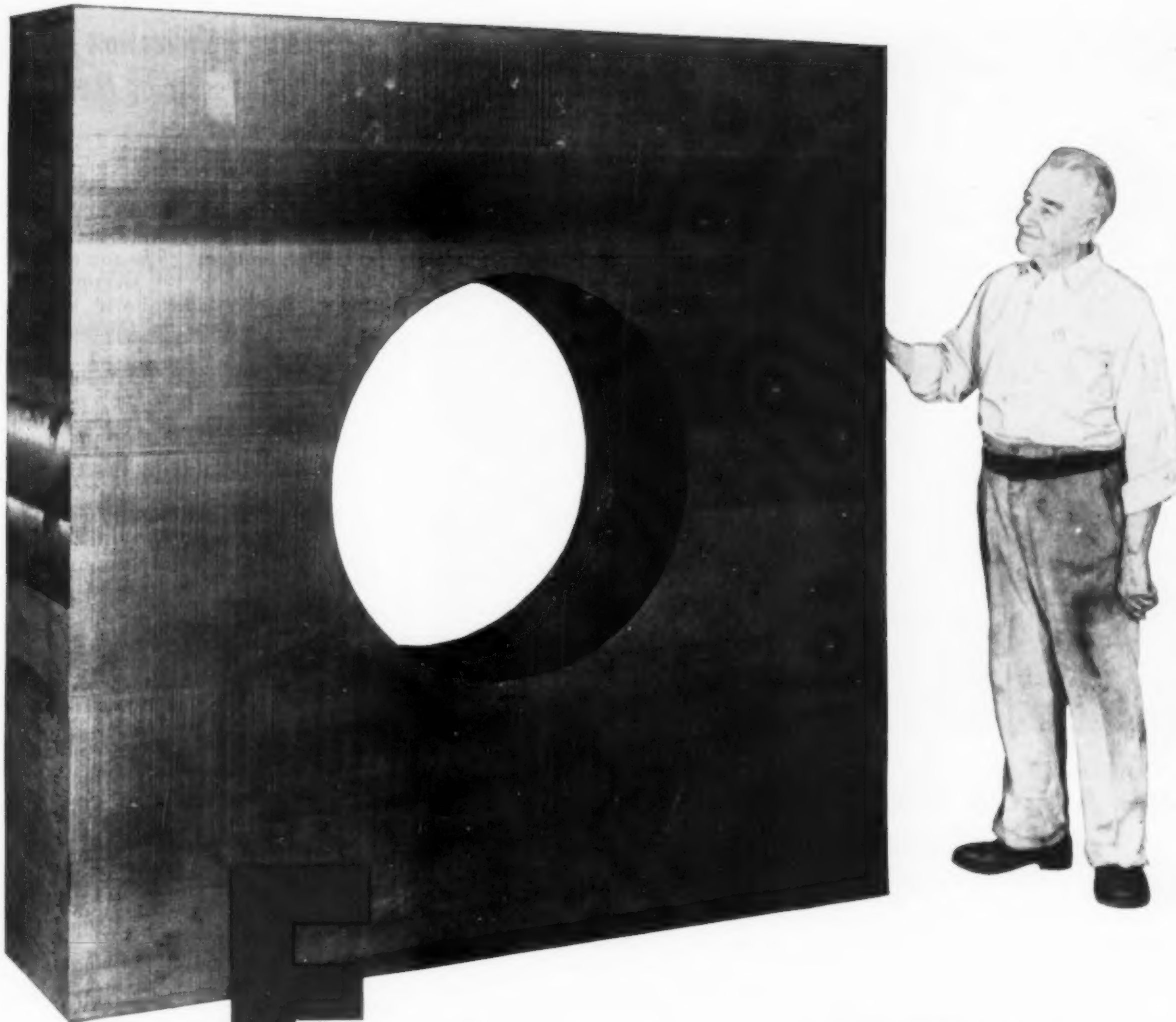

Carbon-Stabilization in Welded Dissimilar Metals Used at High Temperatures*

The welding of dissimilar metals for service above normal atmospheric temperatures offers some rather intriguing problems. The use of austenitic weld metal for joining plain carbon and low-alloy ferritic metal parts was initiated in Germany in 1935 for boiler and pressure vessels and was based on the fundamental idea that, after such welding, a postheat treatment is unnecessary. The resulting service experience with boiler drums welded in this manner necessitated replacement of a major portion of the drums because of leaks. However, austenitic welds in steam pipes of 1% Cr, ½% Mo were generally satisfactory after operation at temperatures of 935 to 950° F.

In the United States during the past 15 years austenitic welds in pipes of 5 to 9% chromium have given quite satisfactory results for hot oil transfer lines. Numerous welds made during the past 5 years using flow nozzles of austenitic steel with carbon steel boiler feed lines are successfully operating in the range of 400 to 450° F. However, the joining of 2¼ and 3% Cr – 1% Mo steam piping having a thick wall to turbine piping of Type 347 stainless has presented a number of major problems.

At the inception of the study described by the authors two major problems were considered to exist: *(a)* The possibility of fatiguing action at the austenite-ferrite interface, caused by differential expansion between austenitic and ferritic materials under cyclic temperature changes; and *(b)* diffusion and migration of carbon from the ferritic to the austenitic material at elevated temperatures. The latter was the subject of the present investigation.

Four plates of 3% Cr – 1% Mo steel, each ½ x 6 x 12 in., were given a 1550° F. normalize followed by a 1325° F. temper. Four plates of Type 347 stainless, each ½ x 6 x 12 in., were water quenched from 2000° F. followed by a 1550° F. stabilizing anneal. The chromium-molybdenum plates were welded to a Type 347 plate using an austenitic weld metal. The four different weld metals used were Type 347 (19% Cr – 9% Ni, Cb-stabilized), Type 316 (18% Cr – 12% Ni – 2% Mo), Type 309 (25% Cr –

*Digest of "Welded Joints Between Dissimilar Metals in High-Temperature Service", by R. W. Emerson and W. R. Hutchinson, *Welding Research Supplement*, March 1952, p. 126s-141s.

12% Ni) and Type 310 (25% Cr – 20% Ni).

Prior to welding, the Cr-Mo plates were preheated to 400 to 500° F., and after welding each plate was cut into two equal parts. One part of each was heated at 1350 to 1375° F. for 1 hr. and furnace cooled. The other part of each welded plate was heated to 1550° F. for 1 hr., furnace cooled to 1300° F., held for 1 hr. and furnace cooled. The former is referred to as "heat treatment A" and the latter as "heat treatment B".

A ½-in. slice was removed from each of the eight test plates. The balance of each of the eight plates was held in a furnace at 1050 to 1100° F. for 3000 hr., followed by holding at 1150 to 1200° F. for 2000 hr. A ½-in. slice was removed from each plate, however, after 1500 and 3000 hr. at the 1050 to 1100° F. level for the purpose of checking macrostructure and hardness.

The side-bend specimens exhibited reasonably good ductility as shown by their ability to withstand the 180° bend test. The free-bend specimens showed elongations across the face of the welds of 18 to 20% and all bent 180° without fracture except the specimen welded with Type 347 and heat treatment A which failed at 75° through the bond with the Cr-Mo plate. Further bending of these free-bend specimens to an outside radius of 1 in. produced fracture of the two specimens welded with Type 310 electrodes and also the specimen with weld metal Type 309 and heat treatment B. All fractures were through the bond with the Cr-Mo plate. The remaining four specimens exhibited partial fracture at the bond.

The transverse tensile specimens all failed in the Cr-Mo plate at elongations of 22 to 25% in 1.4 in. and had reduction of area of 58 to 64%. Yield and tensile values were lower with heat treatment B.

The Charpy bars were located so that the root of the notch was placed as closely as possible to the bond of weld metal with the Cr-Mo base metal and with the notch opening toward the root side of the joint, the notch itself being entirely in the Cr-Mo plate. The specimens with the Type 309 weld metal fractured through weld metal with energy values of 20 to 28 ft-lb. Fractures of the remainder of the Charpy specimens were associated with the bond between weld and Cr-Mo base metal at values which ranged from 6 to 34 ft-lb. Values for the Cr-Mo base metal are 42 and 35 ft-lb. for heat treatments A and B respectively. These data indicate a weakness associated

(Continued on p. 196)

Carbon-Stabilization in Welded Dissimilar Metals

(Continued from p. 195)

with the bond between weld metal and the Cr-Mo base metal.

Hardness surveys indicated that weld metals with heat treatment A were slightly harder than those with heat treatment B. The aging treatment gave a slight hardening to the weld metals and Type 347 plate, and a softening of the Cr-Mo plate.

Microexamination indicated that postweld treatment A did not materially coarsen the Cr-Mo plate but postweld treatment B did develop a coarse grain band in this plate adjacent to the bond. This grain-coarsened band decarburized by migration and diffusion of carbon into the austenitic weld metal. The coarsening appeared to be more pronounced in the specimens welded with Type 347.

Similar processing of test welds between plain carbon, Type 309 and Type 310 plates indicated that grain growth in the carbon steel was approximately 50 times that found in the Cr-Mo plate, and the concentration of carbon in the austenitic weld deposit was also considerably greater. This suggests the marked stabilizing effect of chromium on the carbon in Cr-Mo plate.

VANADIUM AND TITANIUM STABILIZERS

In a second phase of this study the authors investigated the stabilizing effects of vanadium and titanium on carbon migration in joints in carbon and alloy steels welded with austenitic weld metals. The test welds were pipe joints from which specimens for various postheat treatments were machined. The base metals and the weld metals involved were as follows:

1. A 2¼% Cr – 1% Mo pipe of 1⅛ in. wall thickness with one bevel "buttered" with 1% Mo – 0.2% V using 400° F. preheat. Bevel was remachined and the joint was welded with Type 347 electrode using 400° F. preheat.
2. A 2¼% Cr – 1% Mo pipe of 1⅛ in. wall thickness welded to 1% Cr – 1% Mo – 0.2% V using Type 310 weld metal and 400° F. preheat.
3. Titanium-stabilized 5% Cr – ½% Mo of ⅜ in. wall thickness with a piece of 1% Cr – ½% Mo welded on each end using 400° F. preheat. One weld was made with Type 310 electrode and the other with 2¼% Cr – 1% Mo weld metal.
4. Grade B, A106 carbon steel of ⅜ in. wall thickness with one bevel "buttered" with 1% Mo – 0.2% V. Bevel was remachined and the joint was welded with Type 347.

Sections were taken from each of these welded pipe joints and heated to 1200, 1350 and 1500° F. for 24 hr. Similar specimens were identically heated for 48 hr. One specimen from each weld was heated to 1350° F. for 4 hr. The metallographic examination for exaggerated grain growth was made at 25 ×.

After 48 hr. at 1350° F. grain growth had occurred in the 2¼% Cr – 1% Mo adjacent to the austenitic weld metal, but had not occurred in the Mo-V "buttering" layer or in the Cr-Mo-V material. However, after 48 hr. at 1500° F. grain growth had occurred in the Cr-Mo-V plate to a greater degree than in the Cr-Mo plate. Also in this latter instance decarburization was found to extend in the Cr-Mo-V plate beyond the area of exaggerated grain growth.

After 48 hr. at 1500° F. grain growth had occurred in the 1% Cr – ½% Mo plate adjacent to the austenitic weld, but not in the titanium-

(Continued on p. 198)

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Carbon-Stabilization in Welded Dissimilar Metals

(Continued from p. 196)

stabilized 5% Cr – ½% Mo. However, in the 2¼% Cr – 1% Mo weld metal used between these two base metals, considerable grain growth occurred adjacent to the titanium-stabilized 5% Cr – ½% Mo plate, but practically none adjacent to the 1% Cr – ½% Mo plate. This observation suggests that: *(a)* Titanium, because of its strong carbide-forming tendency, prevented carbon migration from the 5% Cr – ½% Mo base metal to the austenitic weld metal, and *(b)* the titanium in the 5% Cr – ½% Mo base metal, being in excess of that required to stabilize the carbon therein, caused carbon migration from the less stable 2¼% Cr – 1% Mo weld metal.

At 1350° F. decarburization is greater in the unstabilized Cr-Mo alloys than in those stabilized with vanadium and titanium. At 1500° F. the vanadium-stabilized steel showed excessive decarburization but the titanium-stabilized alloy did not.

The authors conclude that, "Although the presence of strong carbide-stabilizing elements in ferritic steels is effective in preventing carbon migration from such a material into a high-chromium austenitic weld, care must be exercised to avoid the presence of such elements in excess of that required to stabilize the carbon, if such materials are to be welded with electrodes which will produce weld deposits of relatively lower carbide-stabilizing power.

"Carbon migration in itself is not believed to be a serious problem. The rate of diffusion of carbon at 1050° F. is relatively slow and is believed to be of little significance. High-temperature postweld heat treatments, however, will result in a rapid carbon migration; such treatments for any prolonged period of time would result in more carbon migration than would be obtained in many years at the service temperature. High-temperature postweld heat treatments are, therefore, to be avoided. In placing dissimilar metal joints in service, excessive temperature cycling should be avoided, particularly when the high-temperature side of the cycle is in the scaling range of the low-alloy ferritic steel."

In thinking about this general subject of "carbon stabilization" and the statement with reference to the "excess of that required to stabilize the carbon", I am wondering just how either the welding engineer or the metallurgist would determine whether an excess is present in any particular case. The authors fail to indicate the basis for such determination. Perhaps it is so simple as to need no explanation and I have missed the point in passing.

W. L. WARNER

Nature of Surfaces in Bearings*

GENERALLY there are three phases in the operation of a bearing; namely, a running-in period, a normal service period, and a running-out period. Even with the best designed and manufactured bearing, it is advantageous to start operation under light load with good lubrication so as to remove local asperities from the rubbing surfaces. This elimination may be due to mechanical interference, to localized adhesion, to corro-

(Continued on p. 200)

*Digest of "The Effect of Lubrication and Nature of Superficial Layer After Prolonged Periods of Running", by F. T. Barwell, *Journal* of the Institute of Metals, Symposium on Properties of Metals, 1952, p. 101-122.

Mounting carbide tips is a cinch when you use EASY-FLO NO. 3 TRIMETAL. After cleaning tips and tool surfaces, use a precut shim, or cut shims to fit, preplace them and heat. Anybody can be readily trained to do it. Illustrations show work of this kind being done at the Modern Corporation, Detroit, Michigan.

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Nature of Surfaces in Bearings

(*Continued from p. 198*)

sive action of the lubricant, or to dispersed abrasive particles.

This type of localized wear will lead to initial improvement of bearing performance, which usually will last for a considerable time before continued wear may have detrimental results. If mechanical interference should be very severe, due to high loads and speeds, frictional heat may not be dissipated rapidly enough, and localized seizure may occur. (Complete failure may be delayed or prevented by suitable additions to the lubricant.)

Another type of failure, called fretting corrosion, may develop when mating surfaces, which are supposed to be at complete relative rest, actually move slightly against each other. This fretting corrosion is usually characterized by oxidized debris and pitted contact surfaces. These pits have a different appearance from pits formed in failed ball bearings (usually called flakes). It appears that minute amounts of water vapor and oxygen play an important role during the fretting corrosion.

The friction between rubbing metallic surfaces has been shown to be reduced by the presence of an oxide layer which may prevent metallic friction, particularly under light load. The nature of the oxides formed depends on the mechanical action and on the environment. Tests at the Thorntonhall Research Laboratory, England, indicate that oxidation of fresh metallic surfaces in presence of water leads to formation of the hydroxide radical which may induce changes in the lubricant. It was also shown that formation of oxides while sliding without lubricant depends on the velocity of sliding. The oxides are embedded in the disrupted surface layer. Presence of lubricant modifies the action, and there may be less deformation of surfaces and oxidation. The formation of debris in the presence of surface agents which will cause dispersion may lead to increased rate of wear; under other conditions it may reduce metallic contact by filling surface irregularities and thereby reduce load on the asperities.

While running-in usually consists of a geometric modification of the surfaces by reducing the asperities to promote formation of hydrodynamic lubrication, there may be some high points that will be subject to such high loads that the temperature will

(*Continued on p. 202*)

Nature of Surfaces in Bearings

(Continued from p. 200)

reach the melting point, and "scuffing" will result. Under mild conditions, plastic deformation of the surfaces may smooth them. The structure of the extreme surface itself will affect the size of particles that are removed by rubbing.

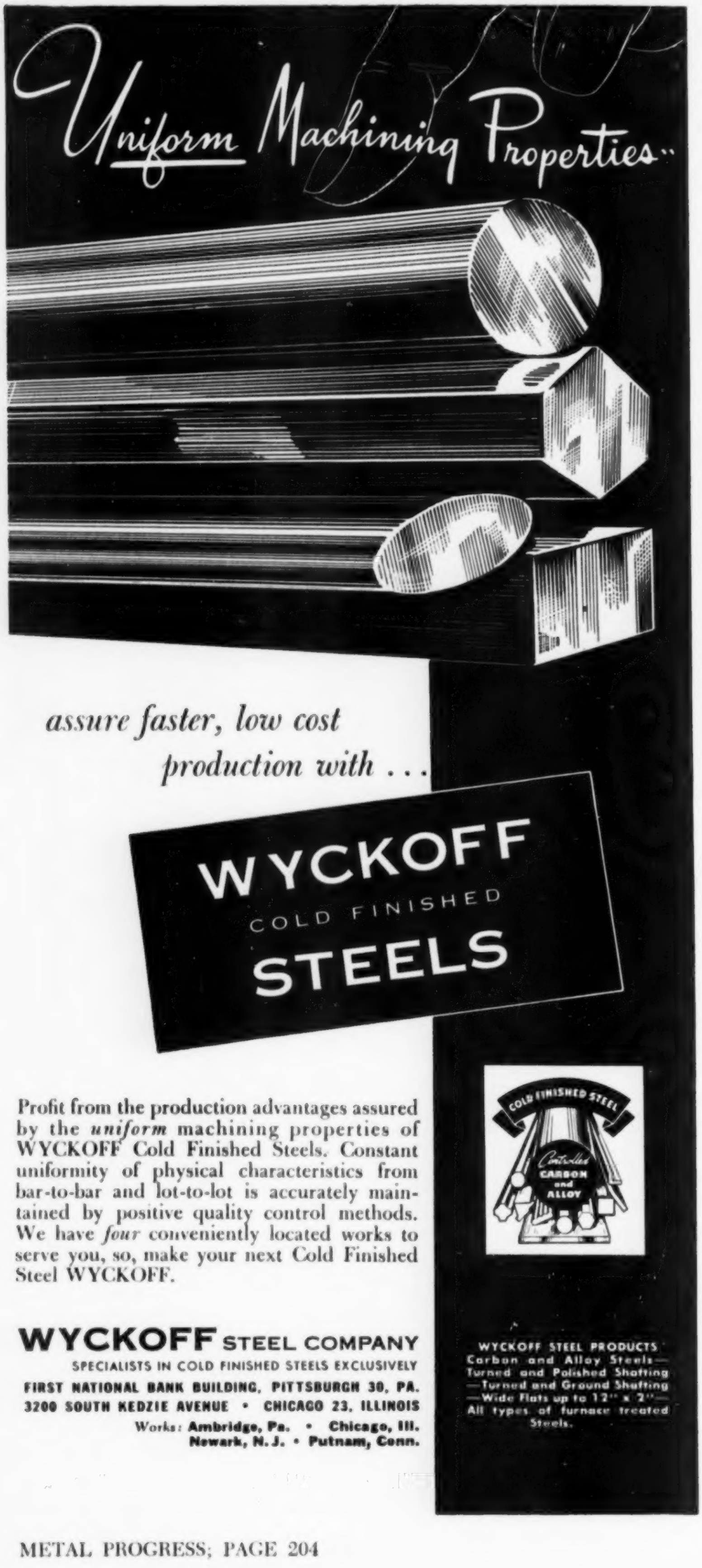
Changes may also occur below the contacting surfaces. In sliding without lubrication there may be plastic deformation on the surfaces, while with lubrication the subsurface will be deformed. The author has studied the operation under light surface-stresses which would not cause plastic flow, but where repeated cycles of stress would cause failure. A four-ball machine used for lubricant testing was modified so that the three balls could rotate freely in a special race. The upper ball would be in rolling contact with the three lower balls and gradually develop a ball track. It was found that the failures were similar to those found in ball bearings, such as pitting, flaking and spalling. By sectioning, polishing and etching of the balls, it was shown that the amount of change in the material under the track would increase with time. (This fact is well known from endurance tests on ball bearings.) Incipient cracks below the surface were also found. It is indicated that such results were obtained under different loads but, unfortunately, no details as to loads and durations of their applications are given, which could have been of interest.

Returning to rubbing surfaces, the effect of chemically modifying the surfaces is discussed. A phosphatic coating is found beneficial for ferrous surfaces because the porous structure which is bound to the underlying surface permits absorption of lubricant and therefore helps to increase the seizure load. It is stated that phosphating is also a valuable palliative for fretting corrosion. The possibilities of using anodized surfaces for overcoming the poor bearing characteristics of aluminum are mentioned but no test results are given, except that surface cracking can occur when sliding occurs under excessive loads.

Factors influencing formation of protective surface films by chemical reaction are the reactivity of the metals, nature of lubricant, the environment, and speeds and loads.

In the presence of oxygen and traces of water a metal hydroxide is formed, and when water is absent, oxide is

(Continued on p. 204)



Nature of Surfaces in Bearings

(Continued from p. 202)

formed. Formation of oxides, and particularly the hydroxide, is necessary for formation of a soap film which gives protection to the metal surfaces for operation under relatively low temperatures. At high temperatures, however, it is necessary to produce substances with higher melting points than of soap to protect the surfaces. For this purpose extreme-pressure additives are used; for example, those having chlorine combine with iron to form $FeCl_2$ which has a lower melting point than iron. Even such film gives limited protection.

In other environments polymerized film may be produced which sometimes may be detrimental and cause sticking, but under other circumstances may be of advantage in reducing abrasive wear. Loads on bearings before incipient failure could be increased when paraffinic oil is used in presence of air, but reduced in presence of nitrogen.

There are evidently a number of factors which influence changes in the surfaces that are in relative motion. When loads and speeds are extreme they may lead to immediate scuffing. When they are less extreme they may help to remove the asperities and improve the bearing configuration for hydrodynamic operation. Environment may be beneficial in forming protective surfaces, but the many factors of importance make generalization impossible.

H. Styri

Accelerated Corrosion Tests of Stainless Steel*

Tests were undertaken to learn whether galvanic corrosion would occur when Type 316 ELC stainless steel plates welded with Type 347 rod were exposed to halogenous acid fumes. Molybdenum is known to impart superior corrosion resistance to Type 316 stainless in such an environment. It was thought that an undesirable combination of a large cathodic and a small anodic area might arise.

The stainless steel was intended to be used for chemical hoods; hence its exposure to hydrochloric and hydro-

(Continued on p. 206)

*Digest of "Accelerated Corrosion Test of Stainless Steel Samples in an Effort to Establish Galvanic Attack", by J. T. Waber and S. F. Waber, Document LA 1302, Los Alamos Scientific Laboratory, Nov. 14, 1951.

Accelerated Corrosion Tests of Stainless Steel

(Continued from p. 204)

fluoric acid fumes was selected as definitive. Plant experience data, supplied by W. Friend of the International Nickel Co., showed that low-alloy stainless steels, such as Type 304, have a lower resistance to attack by fluorides than does Type 316.

The fumes were obtained by partially refluxing dilute acid solutions (5% by volume of concentrated acid) and by passing sufficient air through the test apparatus to dilute the gas mixture. The flow of air was measured by means of a flowmeter. The composition of the gas mixture was calculated from the volume of dilute acid that was evaporated and the volume of air passed through the apparatus. A typical composition of the exit gas was found to be 2.9% HF (gas), 59.6% H_2O and 37.5% air.

A simulated hood was made by inverting a Pyrex crystallizing dish (polytetrafluoroethylene for HF), suspending it over the top of a similar but larger dish by glass hooks and directing an air stream against the bottom of the upper dish. A considerable amount of condensate dripped from the glassware and ran down the specimens to the welds near the bottom. Thus it was possible to see if the corrosion products draining from the upper portion of a specimen affected the passivity of the weld metal or of the heat affected zones.

Three specimen designs were tested. The important feature of one design was that half of the weld was ground flush with the base plate. For another design a pipe coupling was welded to a drilled plate, and for the third the specimen was used as-welded. Control specimens, which had analyses identical with the unwelded plates, were also tested.

A grid was drawn on the specimens and thickness measurements were made before and after each run. Several measurements on each specimen were taken as closely as possible to the region of the weld.

Exposure of the specimens to the aerated, acid fumes for 200 hr. was sufficient to dissolve 0.002 in., or more, of metal from all parts of each specimen. Neither galvanic attack nor streaking, as a result of activation by the corrosion products, was observed in any specimen. Corrosion penetration in the welded plates was practically identical with that in the control specimens. Definite, intergranular attack in the heat affected zone of the

(Continued on p. 208)


W. FISHER
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Accelerated Corrosion Tests of Stainless Steel

(Continued from p. 206)

Type 316 ELC plate exposed to HCl fumes was observed. This attack was more likely a result of precipitation of the sigma phase than of carbide precipitation. In general, Type 347 stainless was found to be several fold less resistant to general corrosion and to pitting in either HF or HCl than was Type 316 ELC. Therefore, the use of Type 347 welding rod was not recommended.

J. T. WABER

Flash Annealing of Aluminum*

THE INCREASED DEMAND for aluminum and aluminum alloy sheets having a uniformly fine grain has required the development of an annealing furnace that would speed their production. The flash annealing furnace described in this article is of the conveyer type for handling of single sheets and consists of two chambers, one in which the sheet is heated to the required temperature and the other in which it is cooled to facilitate handling and to minimize marking of the sheet.

The factors which promote a fine grain size are reviewed, as is the theory of recrystallization. Some examples are cited from literature which show the effect of cold work and annealing temperature on the grain size of aluminum sheet of several purities, as well as several aluminum alloys. It is pointed out that one factor, which is often a dominant one in obtaining a uniform response to recrystallization, is to have a homogeneous state. This factor has become of increasing importance as a result of the widespread use of the direct cooling method in casting ingots.

With all other factors predetermined, the only variables prevailing during the annealing process itself are the rate of heating, the annealing temperature, and the time at temperature. Examples are given to show that of these variables, the rate of heating is most directly related to the grain size. In order to increase heating rates (and thus insure a fine grain size of greater uniformity) during batch annealing or solution heat treating, "such devices as reduction of load weights,

(Continued on p. 210)

*Digest of "Flash Annealing of Light Alloys", by R. T. Staples, *Journal* of the Institute of Metals, Vol. 80, 1951-52, p. 323-334.

Flash Annealing of Aluminum

(*Continued from p. 208*)

use of superheat, high power rating of electrically heated furnaces, and load spacing have all been employed". Examples are given which show the effect of heating rate on grain size. Aluminum of 99.95% purity (single-phase alloy) is not affected by heating rate, aluminum of 99.5% purity shows a slight decrease in grain size with increased heating rates, and two-phase or heterogeneous alloys show a marked decrease in grain size with increased heating rates.

The fastest heating rate in commercial use is obtained in the solution heat treatment of aluminum alloys in salt baths. However, for nontreatable alloys, salt bath furnaces are not practical because of loading and unloading costs, salt dragout and the need for washing and drying facilities. The closest approach to salt bath annealing is obtained in a conveyer-type furnace using convected air.

The increased heating rate made possible by using a superheat or high thermal head in the flash-anneal furnace is discussed. A much higher degree of superheat is possible for flash annealing than for batch annealing where a superheat of 212° F. is seldom exceeded for noncritical treatments and no superheat is permitted for critical treatments. In order to utilize the maximum degree of superheat, an even distribution of the heated air to all surfaces of the sheet is necessary. When heating from a single side, turbulence at the edges causes air to spill to the lower face, which results in a higher temperature at the edges than at the center of the sheet. When employing "air temperatures above 1020° F., a radiation effect is imposed upon the convection effect". This factor limits the degree of superheat, for residual radiant heat from the structure might cause overheating or even melting in the event the conveyer should stop.

The advantages and disadvantages of air flow parallel to the sheet face, both longitudinally and transversely to the direction of the sheet, are discussed. The optimum conditions for heat transfer would appear to result from "multiple-point introduction of the air at 90° to the load, with adjacent off-takes, the full requirement being a set of inlet points above and below the load". However, the amount of turbulence is limited, since the flash annealing furnace would handle circles as well as large sheets. Graphs are given which show that the total

(*Continued on p. 212*)

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Flash Annealing of Aluminum

(Continued from p. 210)

time in the furnace is directly related to gage, and that the rate of heat transfer is independent of gage and speed of conveyer. These factors show the importance of air-to-metal surface relationship in furnace design.

The loading and operational problems are discussed, including the production rate and range of sizes to be handled. It is pointed out that the conveyer design is an important factor in limiting the maximum temperature because of the possibility of marking the soft metal surface as it exits from the heating zone. The cooling rate of the heavier gages may limit the speed of operation.

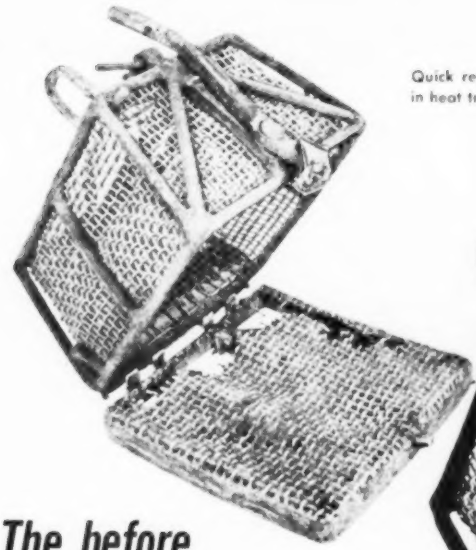
It is assumed that electricity will be the source of heat, and the advantages of battery-type heaters over strip-resistors are given. The effect of surface condition on heat transfer as it affects temperature variation is discussed, as is the need for a reliable way of determining metal temperature.

Although this type of furnace was developed primarily for annealing, the possibility of using it for stress relieving or process annealing hard rolled sheet to produce intermediate tempers is envisaged. However, the data given illustrate the limitation of this process in that by varying the conveyer speed by one foot per minute as the critical point is reached, a sudden decrease in ultimate and proof stress occurs.

The advantages of limiting diffusion in clad strong alloy sheet are stated, as well as the decreased solubility of constituents in heat treatable alloys by employing fast heating rates. However, in annealing these alloys the temperature control becomes increasingly important, since the temperature for recrystallization and partial solution of the soluble constituents may be very close or may even overlap.

It is also stated that such a furnace may be used in the future for solution heat treatment in conjunction with induction heating to obtain an even finer grain size. The flash annealing furnace would be employed as a soaking chamber. A proposal for such application is covered by French Patent No. 959,659.

L. E. HOUSEHOLDER



Microstructural Evidence of Fatigue in Metals*

THE THEORIES presented heretofore to explain the phenomenon of fatigue in metals and alloys assumed that a process of work hardening occurs on the crystallographic slip planes during cyclic stressing. It has been postulated that when the stress in the strain hardened region eventually exceeds the rupture strength of the material, then cracking would occur. No distinction was drawn in these theories between fatigue at high and at low stresses. It was assumed that deformation was associated with slip alone, the degree of stressing would then control only the rate of work hardening, and hence the fatigue life of the metal. Forsyth points out that the characteristic shape of the fatigue curve might suggest that two mechanisms were in operation, the one at high stress and the other at low stress, but the complex nature of the strain hardening process has until now provided an alternative explanation.

It is pointed out, however, that static-stress experiments have shown that deformation mechanisms other than slip (glide) and twinning, which have long been recognized, can occur. The more interesting of these are "kinking", which has been described by Orowan (*Nature*, Vol. 149, 1942, p. 643), and flexural glide, either with or without accompanying relaxation in the form of polygonization (*Progress in Metal Physics*, Vol. 2, Chalmers, p. 149-202). The result of either form of deformation is local variations in orientation; pure glide causes no such change. These variations may be very small, and hence difficult to detect.

Forsyth used recent developments in metallographic technique with the anticipation that features associated with the deformation of metals during cyclic stressing might be brought to light which have possibly escaped observation in previous work. He feels that his recorded observations are sufficiently important to justify reconsideration of the present theories of fatigue.

The fatigue specimens, which were polycrystalline in structure, were in the form of cantilevers, and they were vibrated in apparatus which had been previously described (*Journal of Scientific Instruments*, Vol. 26, 1949, p. 160). The specimen, while undergoing the fatigue test, was examined un-

(Continued on p. 216)

*Digest of "Some Metallographic Observations on the Fatigue of Metals", by P. J. E. Forsyth, *Journal* of the Institute of Metals, Vol. 80, 1951-1952, p. 181-186.

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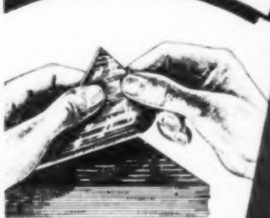

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Microstructural Evidence of Fatigue in Metals

(Continued from p. 214)

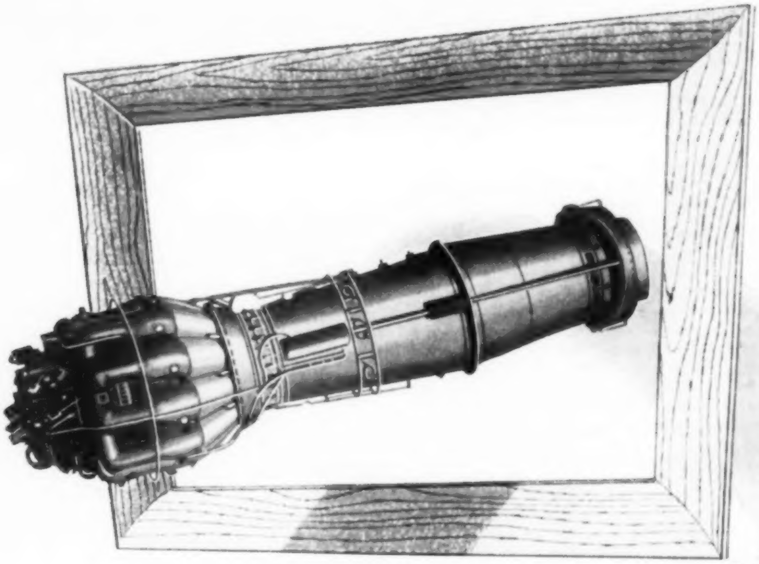
der a microscope using stroboscopic illumination. Most of the tests were made on a high-purity, aluminum – ½% silver alloy, but a few tests were made on commercially pure copper and on Armco iron. The heat treatment of each of these materials is described in the original paper. The heat treated specimens were electropolished without subsequent grinding, so as to insure that no work hardened surface layer existed.

No attempt was made to measure the stresses imposed on the specimen. The reasons given were the complexity of stress distribution introduced by the notch, which was used to localize failure within the field of view, and the fact that the materials were being stressed above their elastic limit. Each specimen was tested under constant strain for that specimen, and the fatigue curve was plotted as strain in arbitrary units (derived from the deflection of the specimen) versus log of the number of cycles of stress undergone by each specimen. The applied stress is merely described as high or low, where the term, high stress, indicates that the maximum stress of the cycle is above the stress level of the "knee" of the S-N curve, and the term, low stress, indicates that the maximum stress of the cycle is below the stress level of the "knee" of the curve.

Many excellent photomicrographs are included in the paper to show the behavior of these materials under high and low stresses. Metallographic study of the structural changes that occur when the aluminum-silver alloy was subjected to cyclic stressing at room temperature led Forsyth to postulate that the process of fatigue in metals is associated with the following phenomena:

Slip occurs at all stresses which lie on the endurance curve. At a high stress level, deformation bands of the "kink" type occur in the early stage of fatigue, and deformation bands form along slip planes as the result of polygonization in regions of high lattice curvature. At a low stress level, only deformation bands of the second type just described are formed.

Crystallites are formed as a result of deformation bands being broken down by subsequent slip, or as the result of polygonization of regions of high lattice curvature, particularly near grain boundaries. The mean value of the crystallite size is about 10 microns, the smallest value being about 1 micron. *(Continued on p. 218)*



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Microstructural Evidence of Fatigue in Metals

(Continued from p. 216)

Final rupture of the lattice takes place in a region of crystallites, although it has not been definitely established whether the resulting crack forms at the crystallite boundary or within the crystallite. Such evidence as has been obtained, however, suggests that cracks originate at the crystallite boundaries. The first crack to form is not necessarily the one which propagates through the metal to produce failure. This would not be very understandable if the region at the root of a fine crack is considered merely as a strain hardened region, subjected to high stress concentration. The explanation of the fact that the first crack may not necessarily propagate is suggested to lie in the formation of crystallites ahead of the advancing crack. The relaxation which is associated with the formation of crystallites would result in a lower rate of strain hardening than would occur in the absence of crystallites. Furthermore, the effectiveness of the crack as a stress-raiser will be reduced by the presence of branch cracks along the crystallite boundaries.

The theory offered by Forsyth seems to be well founded on the basis of the photomicrographic evidence he presents. R. W. LINDSAY

Effect of Degassing and the Metal-Mold Reaction on Soundness of Castings*

As BOTH THESE authors write regarding work carried on in the British Nonferrous Metals Research Association dealing with the same problems, they should be studied as one unit. Mr. Rutherford's work was done prior to 1950 while that of Mr. Mantle was completed in June 1952.

In Mr. Rutherford's work, bars and plates were cast in green sand (known in England as Mansfield) having a moisture content between 5 and 5.5%, of 85-5-5-5 leaded gunmetal; and concurrently two foundries made some tests on small valve bodies. It was as-

(Continued on p. 220)

*Digests of "The Effect of Metal-Mold Reaction on 85-5-5-5 Leaded Gunmetal Sand Castings", by N. B. Rutherford, *Journal* of the Institute of Metals, Vol. 80, 1951-1952, p. 555-568; and "Nitrogen Degassing and Metal-Mold Reaction in the Production of Gunmetal Castings", by E. C. Mantle, *Foundry Trade Journal*, Vol. 93, July 24, 1952, p. 95-100.

Effect of Degassing

(Continued from p. 218)

sumed that a metal having uniformly high density could be produced which would not leak under pressure. (Issue might be taken on this statement.)

In Mr. Mantle's work the same type of alloy was also used, but no information is given as to the kind of mold used. Presumably it was a green sand mold but what precautions were taken to maintain a constant moisture content are not given. This would seem to be an important omission. In place of the bars and plates used by Rutherford, small valve bodies were cast by Mantle to test probability of leakers directly and not by inference.

Agreement is reached in the two experiments that castings made from metal degassed before pouring, together with the correct phosphorus addition to assure good metal-mold reaction and which were cast at the correct low temperature, had higher density and less or no leakers. One example will suffice to show the details of the method recommended. The metal was melted in a 400-lb. tilting crucible furnace, and then degassed with nitrogen. Care was taken to maintain the pressure in the nitrogen tube at not less than 300 psi. to avoid formation of moisture. The nitrogen was introduced by means of a refractory tube at a reduced pressure of 10 psi. for 5 min. After the nitrogen treatment, phosphorus-copper was added to give between 0.05 and 0.08% phosphorus in the final casting.

The work described by each author showed painstaking attention to detail and there is agreement in the results obtained. In the Rutherford article an interesting and informative description is given of the comparison between the "classical experiment" versus the "factorial experiment", and the statistical examination applied with the latter is shown.

Rutherford used a 100-mesh powder of aluminum-magnesium suspended in a volatile resinous base with which the green sand mold is painted to prevent the absorption of gas by the molten metal from the mold. Both workers degas the metal by admitting nitrogen gas beneath the metal through a suitably protected tube. (In this connection it would be well to consider Spire's method of admitting the nitrogen by means of a porous block instead of a tube and thus getting a finely divided spray and greater efficiency.) The basic principle of the metal-mold reaction appears to depend on the assump-

(Continued on p. 222)

Effect of Degassing

(*Continued from p. 220*)

tion that with badly gassed metal enough time elapses during freezing for the dissolved hydrogen to diffuse and concentrate sufficiently at the heat centers to cause leakage under tests. In the case of degassed metal which picks up gas by the metal-mold reaction, the subsequent absorption of gas from the mold is not deleterious because there is then not enough time for diffusion to occur.

Many foundrymen find it hard to believe that deliberate introduction of gas into metal can be an asset in making pressure-tight castings, but the evidence of these two projects points definitely that such may be true – if it is done under the special conditions described. On the other hand, the whole investigation is predicated on the casting having "hot spots" due to design involving heavy and light cross sections being in juxtaposition. Is it not reasonable to ask why castings are designed with this limitation? Therefore, might it not be worth-while to redesign castings to avoid hot spots and then make them with metal that is as gas-free as possible?

H. J. Roast

Internal Stress in Castings*

This is the first report on work undertaken by a subcommittee (T.S. 32) of the Institute of British Foundrymen charged "To investigate the problems of internal stress in castings."

Internal stresses are those stresses which may remain in a casting after it has been removed from the mold, and these stresses exist within the casting or in the casting surface due to no apparent external cause. Internal or residual stresses combined with service-imposed stresses may produce unexpected failure of the casting or warping during machining.

Failure of the sand mold to accommodate the contraction of the casting will, at high temperature levels, produce a hot tear which may be followed by a widening of the crack at lower temperatures. If the rigidity of the mold leads to local plastic deformation in the casting, internal stresses will be present after shakeout. Friction between the mold and casting can cause such stresses during cooling in the mold.

Temperature differences in parts of

(*Continued on p. 224*)

*Digest of "Internal Stresses in Castings", *Foundry Trade Journal*, Oct. 23, 1952, p. 471-477.

Internal Stress in Castings

(Continued from p. 222)

a casting are less obvious sources of internal stress and result from local plastic deformation of one part of the casting. This local plastic deformation produces differences in the amount of contraction for various parts of the casting and gives rise to internal stress. Plastic deformation occurring while the casting is hot does not lead to residual stress and any internal stresses remaining at the time of shakeout will have resulted from plastic deformation at fairly low temperatures. Stresses of internal nature occurring in hollow cylinders are considered to arise mainly from temperature gradients rather than resistance of cores to accommodate contraction.

When transformations occur at different times in parts of a casting, the accompanying volume changes may cause internal stresses. Low-temperature transformations, such as that to martensite, may produce cracks.

Tests in which double-flanged bars were compared with straight bars that had been poured from 66-34 brass into soft and hard-rammed molds revealed little difference in the final contraction due to type of ramming. However, until the time of shakeout, the flanged bar had contracted a smaller amount, indicating that the internal stress was relieved at that time. The distance between the final positions of the plotted curves for the contraction of the two bars is a direct measure of the plastic deformation.

Several tests were conducted by casting an aluminum alloy and a steel in the shape of a triangular grid wherein the contraction of the central heavy member was hindered by the cooler outer frame. In each instance the internal stress of the center member was higher when a cool casting was removed from the mold; for example, the internal stress at a shakeout temperature of 1830° F. was 7500 psi., whereas an internal stress of 20,600 psi. was present when the casting was cool upon shakeout.

When aluminum castings were cooled in the molds, the internal stress increased as the water content of the sand increased from 3 to 8%. Also, internal stress was found to increase as the pouring temperature increased from 1345 to 1450° F. As the diameter of the runner increased from 0.85 to 1.1 in., a marked increase occurred in internal stress.

It is concluded that temperature gradients are the principal factors which lead to the development of internal stress in castings. Any change which produces an alteration in the

(Continued on p. 226)

Internal Stress in Castings

(Continued from p. 224)

cooling of the casting will have a pronounced effect on the formation of such stresses, regardless of the alloy used for the casting. Hot shakeout is recommended to reduce residual stresses. Internal stresses can exist only at temperature levels lower than that at which rapid creep under the stress concerned will occur.

D. C. WILLIAMS

Metal Conservation in Britain*

IN THE MIDDLE OF 1951 a critical shortage of metals appeared imminent in the United Kingdom which was only avoided by a timely expansion in world production, extensive use of alternates by industry and Defense Departments, reduction in defense demands, and restrictions on allocations to industry. As of September 1952, the shortage in lead and zinc has entirely disappeared. Nickel, cobalt and copper still give cause for concern. Other metals are adequate for uses at present not on the restricted list, although there is little margin.

Considerable study is being given by various research institutions to ideas which might result in further economies. For example: Can useful amounts of alloying elements be saved in steels by driving the incidental impurities – particularly phosphorus – to lower levels. As much as 25% of the zinc used in galvanizing can be saved by improved plant practice. Lead-coated steels also seem to have important uses. The British Standards Institution has issued specifications for low-alloy case hardening steels. Modernization of the codes for welded construction reduces the mandatory weights of steel.

Industry itself has worked along a multitude of lines to economize in the usage of available metals, to reduce the amount of circulating scrap, and to segregate meticulously that which is made and return it for recovery.

An important example of the use of an alternative material by industry can be drawn from the field of straight chromium stainless steel. Attention was turned to this material when the use of austenitic 18-8 stainless steel was prohibited for many purposes in

(Continued on p. 228)

*Digest of "Report of the Metals Economy Advisory Committee" to the British Ministry of Supply, Sept. 11, 1952. H. M. Stationery Office, London, England.

Metal Conservation in Britain

(Continued from p. 226)

order to conserve nickel. At first, attempts were made to use sheet steel containing approximately 0.1% C and 14% Cr. It was then found that raising the Cr to 17%, and in some cases adding 0.5% Mo or 1% Ni, improved the deep-drawing properties. Raising the Cr to 22% and adding a carbide stabilizer such as Ti still further improved the deep-drawing properties, while the addition of the carbide stabilizer greatly assisted the welding properties. As in the United States, where this material has been widely used for some time, argon-arc welding has been found to be one of the best techniques for the straight chromium stainless steels. The use of these steels represents a real step forward, and which for some purposes, such as for pans for food-producing and paint industries, they will continue to hold the field.

It was expected that an acute shortage of tungsten would develop in 1952 and satisfactory alternatives to high speed steels containing 18% W therefore received attention by the High Speed Steel Assoc. and by industry. High speed steel drills larger than ⅜-in. diameter are quite satisfactory when the tungsten is lowered to 13.5% if vanadium is increased to about 2%.

Considerable attention has been given to economy in the use of 70-30 cupro-nickel tubes for steam condensers, an alloy widely used in marine service and in power stations in this country and in America. In power stations the 30% Ni alloy is now stipulated for use only with cooling waters having such a degree of contamination that the only possible alternative which is well tried and readily available – aluminum-brass – is unsuitable.

Other alternative materials are being studied. The U. S. authorities have specified as an alternative a copper-based alloy having 10% Ni, 1.5% Fe. So far there has been no large-scale operating experience. A 12% alpha-tin bronze alloy is also under test.

Economies in the use of copper in electrical cables has been widely canvassed. Aluminum (steel cored) is already well established for overhead transmission lines.

Supplies of nickel anodes to users have been restricted to about 50% of normal. This has seriously affected the efficiency and quality of plating

(Continued on p. 230)

Metal Conservation in Britain

(*Continued from p. 228*)

work. Sufficient comparative data are not yet available on the alternative plating processes (for example, tin-bronze, tin-nickel, tin-zinc, bright zinc, chromium on copper) for a final view to be taken.

The difficulties that arise in promoting metals economy spring mainly from the problems a manufacturer faces when changing materials or designs. This can rarely be done without factory changes. New plant is frequently required, involving capital outlay, and time delivery of new plant is particularly protracted. Costs may be increased for a time. New working techniques are sometimes called for, both by the manufacturer and by his customers. And a manufacturer can usually expect (or actually does expect) consumer resistance to the "substitute" product, no matter whether the product is satisfactory or even an improvement on standard practice.

Corrosion Structures*

CORROSION OF METALS never occurs in a completely homogeneous manner. Continuous corrosion, which occurs often in strongly corrosive media, is relatively uniform, but pronounced heterogeneity characterizes localized corrosion, intercrystalline corrosion, corrosion cracks, and the preferential corrosion of one of the metals of a solid solution. In all cases, including that of so-called uniform corrosion, a "corrosion structure" is produced.

Ordinarily the development of corrosive attack occurs in the following stages which may overlap: Induction period, development of a microstructure, development of a block structure of the grains themselves, and formation of a corrosion structure. Because of the pronounced relief of most corrosion structures, it is not practical to use high magnification in ordinary metallography. At moderate magnifications the binocular microscope is useful. The electron microscope and the profilometer have been used at high magnifications.

The investigations by Deryagin have shown that corrosion structures develop both in nonoxidizing and in various oxidizing media. Thus, corrosion structures were clearly devel-

(*Continued on p. 232*)

*Digest of "Structure and Corrosion", by G. V. Akimov, *Izvestiya Akademii Nauk SSSR, Otdelenie Khimicheskikh*, 1951, p. 469-480.

Corrosion Structures

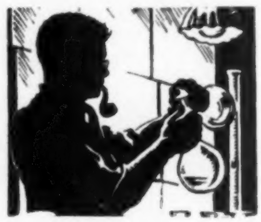
(Continued from p. 230)

oped on pure aluminum, a 1% iron-aluminum alloy, spectroscopically pure zinc, and a 1% iron-zinc alloy by a nonoxidizing solution ($3N$ HCl) and by three oxidizing solutions ($3N$ HCl + $0.6N$ H_2O_2, $3N$ HCl + $2N$ KNO_3, $3N$ HNO_3). The latter solutions tended to produce a coarser corrosion structure. In some instances, such as that of iron, the pure metal and its alloys have similar corrosion structures; on the other hand, the corrosion structure of the 1% iron-aluminum alloy is quite different from that of pure aluminum. Presumably, the initial microstructure influences the development of the corrosion structure and causes this difference in behavior.

Corrosion tests were run for 5 min. in solutions such as those listed above and for 1000 hr. in an aerated 3% NaCl solution using high purity aluminum, iron, zinc, cadmium, copper, lead, and various of their alloys. These tests showed that the addition of an oxidizing agent to a nonoxidizing acid solution may either increase or decrease the rate of corrosion, and that the addition of an alloying element to a pure metal may also either increase or decrease the rate of corrosion. Schematic polarization diagrams were used to show how a cathodic impurity might increase the rate of corrosion of a pure metal in an oxidizing solution.

Electrochemical corrosion of metals is the result of a series of elementary processes: (*a*) Transfer of the metal ion from metal to solution – the anodic process; (*b*) discharge of excess electrons at a cathode of the solution – the cathodic process; (*c*) movement of excess electrons from the place where they are produced to where they are discharged – the electronic current in the metal; (*d*) movement of ions in the electrolyte – the phenomena of electric current in the electrolyte. The anodic regions are not distributed merely statistically; their locations are determined by various inhomogeneities, even in pure metals. Also, the positions of the anodic regions can change during corrosion.

A. G. Guy



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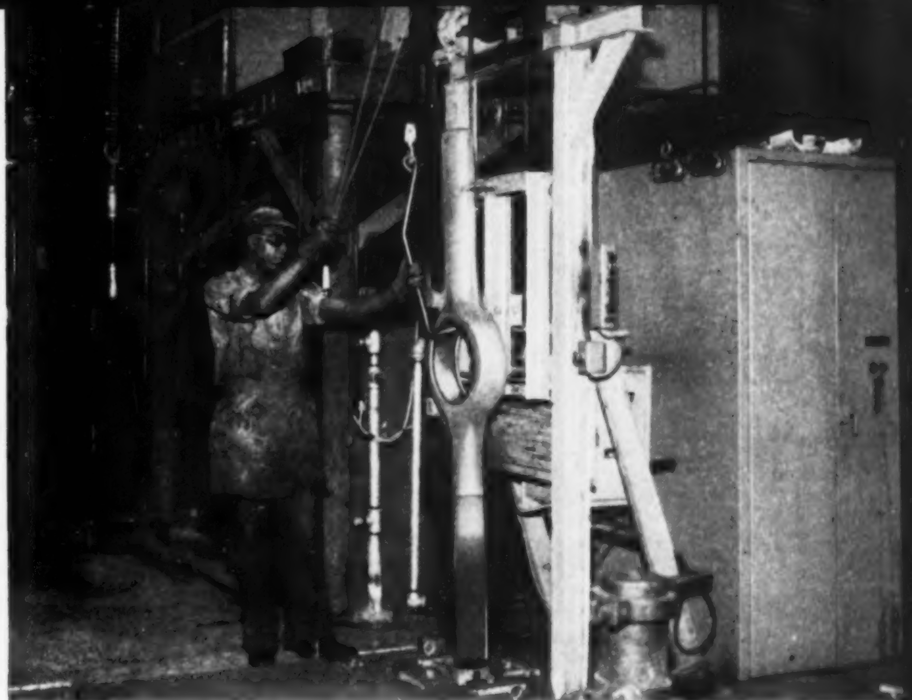

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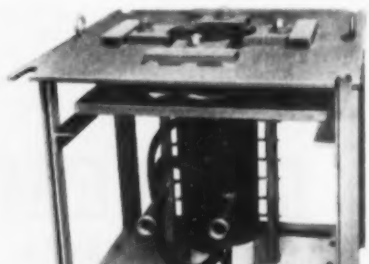

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